WP2

United States

Short Country Report

AUTHOR

Paul R. Josephson

BENEFICIARY

Colby College, Waterville, Maine, USA

Version: July 2018

HoNESt History of Nuclear Energy and Society

This project has received funding from the Euratom Research and Training Programme 2014-2018 under grant agreement No. 662268.

HoNESt History of Nuclear Energy and Society

United States Short Country Report

July 2018

PARTNERS

PROJECT COORDINATOR

Universitat Pompeu Fabra Barcelona

PROJECT PARTNERS

University of Antwerp
UAB Universitat Autònoma de Barcelona
uclan University of Central Lancashire
Colby College
Hellenic Republic National and Kapodistrian University of Athens
Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
University of Copenhagen Faculty of Humanities
Deutsches Museum
DIALOGIK
EHU Europos humanitarinis universitetas
TU/e Technische Universiteit Eindhoven University of Technology
Friedrich-Schiller-Universität Jena
Swedish Defence University
GRE
KTH
LUT Lappeenranta University of Technology
upna Universidad Pública de Navarra Nafarroako Unibertsitate Publikoa
UPMC Sorbonne Universités
The University Of Sheffield.
Science Museum
spi Sociedade Portuguesa de Inovação

CONTENTS

1. Historical Context (Narrative) 6

1.1. Contextual narrative: Experts and the Public in the US in the Years of Nuclear Power 6

1.2. Presentation of Main Actors: US Nuclear Industry and Society Actors 12

1.3. Actors: Narrative Discussion 16

2. Showcase: Early Demonstration Projects: From Nuclear Utopianism to Public Concern22

3. Events 29

3.1. Event 1: Licensing and Operation of Enrico Fermi (Detroit) Breeder Reactor 29

3.2. Event 2: Licensing and Protest over Diablo Canyon NPP and the Abalone Alliance Protests33

3.3. Event 3: Three Mile Island, Pennsylvania, 1979 38

3.4. Event 4: Seabrook Nuclear Power Station and Clamshell Alliance Protests 45

3.5. Event 5: Davis-Besse NPP Operation and Reactor Head Corrosion (2002) 49

4. Facts and Figures 54

4.1. Data summary 54

4.2. Key dates and abbreviations 54

4.3. Map of nuclear power plants 56

4.4. List of reactors and technical, chronological details 57

4.5. List of influencing actors 60

5. References 61

6. Appendix 1: Current Status and Plans: Nuclear power in the US 68

7. Appendix 2: List of Anti-nuclear Groups in the US (from wiki) 73

8. Appendix 3: Reactor Safety Studies 75

9. Appendix 4: Radioactive Waste and Spent Nuclear Fuel 78

Executive summary

This report belongs to a collection of 20 short country reports on the History of Nuclear Energy and Society (HoNESt, project Ref.662268). The reports tackle the complex sociotechnical system around nuclear energy. Nuclear developments, notably nuclear energy, are closely intertwined with social, economic, environmental, political and cultural spheres. Nuclear energy is also a globalized system involving transnational transfers of knowledge, materials, technologies, people and products including electrical power, medical elements, toxic wastes and other environmental hazards, materials, capacities and knowledge that must be carefully safeguarded. Nuclear energy is a complex social and technological phenomenon that influences societies but is also shaped by societies.

The short country reports are designed to assemble information and research results on the history of the relations between nuclear energy and society about all the different country cases in an accessible manner, and to document the findings with references.

The purpose of the country reports is threefold, addressing three different audiences:

1. to provide basic elements of narrative and analysis for further historical research by HoNESt researchers;
2. to provide information, context and background for further analysis for HoNESt's social science researchers;
3. to provide accessible information on nuclear-societal relations in the various countries for the purposes of outreach and communication with stakeholders (civil society, industry, associations, policy makers, journalists).

This report focuses on the history of the relations between nuclear energy and society in the United States. The US experience is crucial in the worldwide and European contexts for understanding public-industry interactions with nuclear power over time, and also how such issues as risk, safety, regulation, and others have evolved. As a leader in nuclear power, US developments are relevant for technology transfer, regulatory approaches, and safety-risk issues – even when it follows rather than leads in these areas. The United States, along with Russia, the United Kingdom, and others, was among the first nations to commercialize nuclear power, beginning in the 1950s. Roughly one-quarter to one-fifth of all power reactors in the world were operated or are still operating in the US – currently 99 of them. Such US manufacturers as Westinghouse/Toshiba, General Electric, and Combustion Engineering have built or plan to build a large number of reactors in Belgium, Spain, and Brazil, China, South Korea, India, and elsewhere, with orders secured for the next ten years or so.

The US nuclear power program took off in an atmosphere of competition with the USSR. At first, reactor development unfolded in a number of national laboratories and remained largely secret to the public until the birth of the international "Atoms for Peace," an effort to share nuclear knowledge for medical, industrial, power production and other purposes to defuse growing Cold War tensions. In this environment the US government and its Atomic Energy Commission (AEC) pushed for rapid commercialization. The AEC moved ahead with certainty that it could manage the new technology. Yet the AEC kept a number of findings and reports including reactor safety studies out of public view, and later ones faced criticism for methodological and other shortcomings in these reports. (Gomberg, 1957; US AEC, 1957; US AEC. 1973; US NRC, 1975). Even recognizing the nascent stage of the industry and technology, the AEC engaged a series of *ad hoc* procedures when it initially considered construction and operating licenses. Its staff was small, often lacking specialists in important areas of nuclear physics, material science, hydrology, geophysics and so on. It often relied on industry for expertise. The result was the acceptance of designs that many in the public believed were not safe enough, and the siting of stations in unsafe areas or areas too close to population centers: a breeder reactor in Detroit, MI (Enrico Fermi), close to earthquake faults (Bodega Bay and Diablo Canyon, CA), and close to cities (Ravenswood in the Bronx, NY, and Indian Point, 65 km north of New York City, and many others). Ultimately, the AEC suffered from "agency capture"; it was beholden to the industry it was designated to regulate.

Anti-nuclear sentiment grew during the anti-war, environmental, civil rights and women's rights movements of the 1960s, triggered in part by the horrors of Vietnam and exposes on environmental degradation, especially the publication of Rachel Carson's *Silent Spring*. The passage of the National Environmental Protection Act (1969) contributed to this questioning, while the Freedom of Information Act (1966) enabled greater scrutiny of government action, including regulation of nuclear power. The publication of AEC documents, studies and deliberations led to a new, critical, and even untrusting relationship between the public and the nuclear industry.

To rebuild trust and ensure safety of the public, the government established the NRC in 1974 “as an independent agency” to ensure “safe use of radioactive materials” while “protecting people and the environment.” (US NRC. 2016a.) Yet ongoing mass protests over the licensing of the Diablo Canyon and Seabrook stations in New Hampshire suggested that oversight did not mean an end to public concerns. Costs increased rapidly as did time for licensing and construction, with two major bankruptcies (PSNH and WPPSS in Washington state known by some as “WHOOPS”), and power generation costs were much higher than predicted. (Mooz, 1979; Pope, 2008)

A partial meltdown at Three Mile Island (TMI) near Harrisburg, Pennsylvania, in 1979, persistent problems at the Davis-Besse NPP in Ohio, and other accidents and events have indicated that industry safety culture was too passive and that NRC supervisory functions have improved but were lacking in many ways. These conclusions come from the NRC itself and the GAO, not from outside public interrogators alone, and have unsettled the industry. (e. g., US GAO, 2006)

Yet public oversight and protest – so crucial in the 1970s, 1980s, and 1990s – waned as industry ceased building new reactors after TMI. The question is whether the public will become active again as the NRC begins to review licenses to prolong the operation of existing stations and as new applications to construct and operate are submitted to NRC offices in response to federal incentives to invest in nuclear power in the 2005 Energy Act. Industry is prepared for nuclear renewal with extensive research, PR, and other groups to educate the public about the benefits of nuclear power.

Public opinion about nuclear power has evolved over several periods, and even against a backdrop of concern, at times mistrust, and such accidents as TMI and Chernobyl, a majority of Americans until quite recently in the twenty-first century seem to have positive attitudes toward it.

1. Historical Context (Narrative)

1.1. Contextual narrative: Experts and the Public in the US in the Years of Nuclear Power

At the end of World War II, after the design and production of nuclear bombs at Los Alamos, NM, and the destruction of Hiroshima and Nagasaki in August 1945 with nuclear bombs, a debate broke out about how to control and manage nuclear technology. In the end, with the passage of the Atomic Energy Act of 1946 (the McMahon Act), the US government created the Atomic Energy Commission (AEC) to establish civilian control – not military – over this nuclear knowhow and technology. By the late 1940s and 1950s, a series of research programs using experimental reactors, isotopes, and the like established the likelihood of applications from power generation to medicine, industry, and agriculture, and to transportation that developed largely in AEC-controlled national laboratories. Yet from the start the AEC suffered from two weaknesses in the effort to promote nuclear power. One was that, at least initially, the AEC commissioners were fully beholden to military interests; the unfolding Cold War and fear of communism led to a headlong rush into designing and testing better nuclear weapons. The second is that the AEC was ultimately "captured" by the industry it was meant to regulate, and when it embarked on civilian power production this was reflected in a closed managerial style that was handicapped by the absence of sufficient internal expertise to ensure that reactor design and siting erred on the side of civilian safety. Procedures to enable public scrutiny toward the ends of safety and efficacy were absent. The AEC developed *ad hoc* procedures for dealing with new challenges and uncertainties (seismic concerns, LOCAs, and so on).

On December 8, 1953, President Dwight D. Eisenhower delivered his "Atoms For Peace" speech at the United Nations to balance fears of nuclear arms race with the hope of renewed interest in peaceful uses of nuclear power through the sharing of nuclear knowledge, knowhow and materials throughout the world. This led the House and Senate to pass the 1954 Atomic Energy Act to promote private development of nuclear energy, with the AEC providing a variety of incentives and, in the eyes of many critics, paying inadequate attention to various safety issues in the effort to promote nuclear power. As Mazuzan points out, the 1954 AE Act gave the private sector the right to own nuclear materials and operate its own nuclear facilities:

> Under the broad authority of the 1954 Atomic Energy Act, the AEC pursued a policy based on the premise that private industry could bring about economically competitive atomic power faster than a government-run program. This policy reflected the pro-business orientation of the Eisenhower administration. Success rested in large measure with AEC chairman Lewis L. Strauss, a strong-willed man with a remarkable talent for being constantly at the center of stormy controversy.(Mazuzan, 1980: 342)

Granted, safety problems became increasingly clear as reactor technology developed – and more complex as reactors grew larger in size, to 1,000 MW units and larger. Supervising the activities of the AEC was Congress's Joint Committee on Atomic Energy (JCAE) which was abolished in 1977 after the creation of the Nuclear Regulatory Commission in 1974.

THE...INVENTIVENESS OF MAN SHALL...BE...
CONSECRATED TO HIS LIFE...
...TO FIND THE WAY BY WHICH
ATOMS FOR PEACE
3¢ UNITED STATES POSTAGE 3¢

A US post office stamp indicating the national message of "atoms for peace" (l); President Eisenhower speaking at the United Nations, December 1953 (r)

In January 1955 the AEC announced a Power Demonstration Reactor Program, "designed to open the way for American industry to develop, fabricate, construct, and operate experimental reactors." There were a number of promising reactor designs from Pressurized Water Reactors (PWRs) to Boiling Water Reactors (BWRs), to Liquid Metal Fast Breeder Reactors (LMFBRs), and different fuels including natural uranium, enriched uranium and plutonium. It was not clear that the PWR and BWR would become the mainstays of the industry. Throughout the demonstration program, from 1955 to 1963, the AEC offered funding to private companies for conducting research and development on proposed reactor designs; waived charges for the loan of source and special nuclear fuels for up to seven years; and provided free research and development in government laboratories for certain mutually agreeable projects.(Mazuzan, 1980: 343) This established a tradition of direct and indirect subsidies to the private sector industry that persists into the 2010s, for example through insurance.

The utilities, engineering firms and manufacturers in the US essentially decided upon two reactor types, PWRs (largely Westinghouse models) and BWRs (largely General Electric models). Both PWRs and BWRs use enriched uranium as fuel and water as both coolant and moderator, to slow down neutrons. The major difference between these two types of reactors is that the PWR has water at over 300°C under pressure in its primary cooling/heat transfer circuit, and generates steam in a secondary circuit while BWR makes steam in the primary circuit above the reactor core" (CLP, 2013)

Insurance and Indemnity

To encourage industry to join in on the AEC reactor push, the US Congress passed the Price-Anderson Act (1957) with a limit on liability of $560 million. The industry was required to obtain as much insurance as the private insurance pool would provide and the federal government would provide the rest of the insurance up to a maximum amount of $500 million. Since the private insurance companies were willing to put up only $65 million, a tiny sum compared to the damages that might result from a meltdown, the federal government determined to pick up the rest. Critics of the proposal pointed out that, not only would the public taxpayer be paying for private industry's insurance, but that the limit might leave thousands of victims unindemnified in case of a catastrophic accident (see Reactor Accident Safety Studies, Appendix 5 below), and the public (through the US government) would be responsible for any further cleanup and other costs.[1]

In simple terms, Price-Anderson covered a 10-year term. All stakeholders hoped that during that ten-year period the industry would gain experience, that the problems of reactor safety would be to a great extent solved, and also that the insurance industry would develop experience on which to base a strong program of their own. Since 1957 the Act has been extended several times, most recently in the Energy Policy Act of 2005 that extended it through December 31, 2025, and offers the nuclear power industry roughly $12 billion in liability insurance protection to compensate the public in the event of a nuclear accident.

---

[1] A legal specialist on nuclear energy noted approvingly that "considerable talent and time were spent in drafting the Price-Anderson Act, and it seems to have accomplished its primary purpose of encouraging private enterprise in the field of atomic energy by providing protection from the danger of financial ruin."(Bangs, 1961: 1180-81)

As an anti-nuclear specialist pointed out in 1965, Price-Anderson enabled a significant and direct government subsidy to the industry. He suggested that the AEC suppressed a study it commissioned by Brookhaven National Laboratory specialists to complete on reactor accidents and insurance. This report, called WASH-740, considered the effects of a “maximum credible accident,” at 3.400 fatalities, 43,000 radiation injuries, and $7 billion property damage spread over an area of 150,000 square miles (perhaps $55 billion in 2016 dollars). (Pesonen, 1965: 242-244)

Financial Challenges to the Nuclear Industry and Growing Costs

Subsidies to the industry through Price-Anderson, rate hikes awarded before power generation, and other considerations have helped the nuclear industry. Yet cost overruns have plagued it. There is a lot of debate about the true costs of nuclear power (capital costs, fuel costs, operating costs, waste management costs) compared to other forms of energy production. But the fact remains that nuclear reactors cost on the average in the 2010s $6 billion per 1,000 MW installed, and since the first station was built not one has come in under its initial cost estimates, although the Russian company, Rosatom (see Russian country report) intends construction at significantly lower costs for current projects. The efforts of industry and regulatory agencies to speed the introduction of nuclear power and fulfill the promise of low costs failed. In 1969, nuclear plants projected for completion in 9 years were expected to cost about $226 per kilowatt hour. In 1978, with an anticipated 12-year construction period, estimates increased to $1,648 per kilowatt hour. (Nelkin, 1981: 132; Mooz, 1979)

One of the greatest failures in this environment of growing costs – and skyrocketing cost uncertainties – involved the Washington Public Power Supply System (now Energy Northwest), a public power joint operating agency formed in 1957 to produce at-cost power for northwest utilities. WPPSS became commonly known as “Whoops” due to its over-commitment to build five large nuclear power stations in the 1970s which brought about its financial collapse and the second largest municipal bond default in U.S. history. (Pope, 2008)

The Energy Policy Act of 2005 offered extensive subsidies for nuclear power and other alternatives to fossil fuels. It offered billions of dollars in tax credits, and loan guarantees for advanced nuclear reactors or other emission-free technologies up to 80% of the project cost, $2 billion in insurance to cover licensing delays to the industry, extension for 20 years of the Price Anderson Act for nuclear liability protection, and support for advanced nuclear technology. Opponents of these costs question subsidization of such an industry in a free market economy. Yet there appears to be great support in Congress for the industry in spite of the history of cost overruns. (Alexander, Whitehouse, 2016)

Experts, the Public and Decision Making in Nuclear Power

How did the nuclear energy industry acquire such great strength and the ability to construct over 100 reactors given these cost and other considerations? Granted, nuclear power stations generally operate within accepted parameters, although there have been significant dangerous incidents and accidents at Fermi NPP, TMI, Browns Ferry, and Davis-Besse as described in this report. One explanation for the strength of the industry is the special prestige of scientists owing to their success in the Manhattan Project and their role in the unfolding Cold War military-industrial struggle with the USSR. Scientists generally played a major role with little public concern about their power and influence in federal agencies in technology assessment until the 1970s. Then, scientific and technological debates widely entered the public sphere and scientists themselves were subjected to great scrutiny for their views. A variety of industries introduced their own experts to influence debates over technology and safety at this time, and as has been demonstrated in some cases used their experts to subterfuge the truth and mislead the public about climate, sweeteners, and tobacco. (Conway, Oreskes, 2010)

As Balogh shows for nuclear power, at first civilian officials and experts in the AEC and JCAE in Congress successfully pushed the nuclear agenda without public intercession. Government officials and scientific experts desired nuclear power, if consumers did not and private companies were not interested in building expensive reactors against financial and scientific uncertainties. This required government officials to be salespeople who advanced arguments about national security and who convinced Congress to provide a variety of expensive direct and indirect subsidies. Further, in the 1970s, as more and more experts and groups entered controversies over nuclear power, citing, safety and so on, the public grew restive and confused, and this contributed to the decline of nuclear power by effectively tarnishing the reputation of experts. (Balogh, 1991) Balogh concludes that government officials must open the policy-making process fully in the early stages and "test for demand rather than seek to create it artificially"(Balogh, 1991: 326).

In his analysis, similarly, Stever called for greater openness and for the involvement of the public early on in technology assessment. He argued, for example, in nuclear power that station siting issues should be made publicly and early on, not after a utility has invested a great deal of time and money to justify a site. He demonstrated clearly that the NRC routinely licenses plants on extremely thin financial, safety, and environmental evidence. For Seabrook NPP neither state nor federal environmental review had a significant impact on the choice of sites or the range of alternates considered. As others have noted, the NRC all too often and in this case accepted the utility's safety information on faith since it lacked capability to make independent evaluations. Stever concluded that time-consuming licensing processes were more the result of the NRC's inefficient way of doing business, not the product of environmentalist delay tactics. All of this called for a more independent and objective NRC. (Stever, 1980: 168).

In a study of opposition to Diablo Canyon, Wills argues that antinuclear activism in California reflected more concerns about "about human ties with nature" than East-West competition (Wills, 2006: 9). This antinuclear activism was splintered, not hegemonic, for example, with disputes over the Sierra Club executive board's initial decision to endorse PG&E's selection of the Diablo site as a way to protect other pristine nature. (Later, worries about seismic faults and TMI turned the Sierra Club away from nuclear power; in 2018 the Sierra Club remains strongly opposed to nuclear power.) Wills illuminates the mass demonstrations of two groups, the Mothers for Peace and the Abalone Alliance, who were certainly motivated by pacifism and counterculturalism, but whose environmentalism was crucial to their mobilization against nuclear power. Wills also demonstrates how not only inept regulation, corporate mismanagement, and rising construction costs led to the decline of nuclear power in California, but also how these groups and other citizens used local and state agencies to block projects. Ultimately, their activities contributed to the creation of the antinuclear California Energy Commission in 1974 and to the passage of antinuclear state level legislation in 1976. The struggle for a clean, healthy environment was most important among the middle-class and well-educated members of the struggle. (Wills, 2006)

1.2. Presentation of Main Actors: US Nuclear Industry and Society Actors

Government

AEC (Atomic Energy Commission) → NRC (Nuclear Regulatory Commission w/ large staff and 5 commissioners). See Appendix 4, country report, for NRC Organizational Structure

- Atomic Energy Acts of 1946 and 1954
- 1955 Power Demonstration Reactor Program
- AEC → NRC in 1973-74

JCAE (Congress's Joint Committee on Atomic Energy)

The JCAE, created by the AE Act of 1946, combined legislative powers with exclusive access to the information, much of it secret, upon which its own often secretive deliberations were based. The JCAE was also entitled by statute to be kept "fully and currently informed" of all AEC activities and vigorously defended its prerogatives. The JCAE was abolished in 1977, three years after the replacement of the AEC by the NRC. In the 1950s the JCAE leadership often came into conflict with the AEC over its own secrecy, for example a new program to push NPPs under AEC chairman Lewis Strauss.

DOE (Department of Energy, grew out of separation of AEC regulatory and promotional responsibilities)

DOE and DOD national laboratories (budget allocations in 2015):

Lawrence Berkeley National Laboratory, Berkeley, California	$570 million
Los Alamos National Laboratory, Los Alamos, New Mexico	nearly $2 billion
Oak Ridge National Laboratory, Oak Ridge, Tennessee	about $1.1 billion

Sandia National Laboratories, Albuquerque, New Mexico	$1.8 billion
Idaho National Laboratory, Arco and Idaho Falls, Idaho	$950 million
Lawrence Livermore National Laboratory, Livermore, California	$1.2 billion
Savannah River National Laboratory, Aiken, South Carolina	$1.4 billion
Pacific Northwest National Laboratory, Richland, Washington	$500 million

(DOD) Department of Defense

The US maintains roughly 1,500 nuclear weapons. According to its The 2010 Nuclear Posture Review (NPR, April 6, 2010), its goals are to prevent nuclear proliferation and terrorism; reduce the role of nuclear weapons; Maintaining strategic deterrence and stability at reduced nuclear force levels of its nuclear triad of bombers, submarines and missiles; strengthening regional deterrence and reassurance of U.S. allies and partners; and sustaining a safe, secure, and effective nuclear arsenal.

The US has spent almost $9 trillion on nuclear weapons, a figure makes the stated goal of “non-proliferation” unfathomable.

EPA (Environmental Protection Agency). Regulators.

GAO (General Accounting Office). Investigations of government bodies and their compliance with their statutory responsibilities.

Industry Actors

The US nuclear industry consists of major manufacturers of reactors, operators and owners, and the NPPs. See appendix 4 (p. 49) for a list of these operators, owners, and holding companies of NPPs.

Major US Reactor Manufacturers

General Electric/Hitachi

Westinghouse

Babcock and Wilcox

Fuel Suppliers

- Urenco USA
- USEC (Centrus)
- GLE (Global Laser Enrichment)

Current Major US Nuclear Operators and Owners

Entergy Operations Inc.

FirstEnergy Nuclear Operating Company

Exelon Generation Company

Luminant

PG&E

WPPSS

TVA

Duke Energy Progress

NRG Energy

NextEra Energy

The Public

NGOs

- Sierra Club
- NRDC
- UCS

Unions (laborers)

Protest Organizations and Anti-nuclear Groups. See Appendix 2 for a partial list of these groups.

Individuals

The Media

Newspapers

Radio

TV

Press centers, public information offices

PR offices

Independent journalists

Documentary makers

Academics

NGOs

Filmmakers

“Webpages” from a variety of different sources

1.3. Actors: Narrative Discussion

The main supporters of nuclear energy in the United States are government bureaucracies including the Department of Energy and the Nuclear Regulatory Committee, the latter which, however, is responsible for oversight and regulation, not promotion, and such government laboratories long connected with military as well as civilian tasks as the Oak Ridge, Los Alamos, Livermore, Hanford, and Idaho; private companies including reactor manufacturers, utilities, operators, and owners; and trade associations representing the industry including the National Energy Institute.

The DOE has several offices and programs connected with nuclear issues (military, security, proliferation, energy, fission and fusion). “The Office of Nuclear Energy’s (NE) primary mission is to advance nuclear power as a resource capable of making major contributions in meeting our Nation’s energy supply, environmental, and energy security needs. We seek to resolve technical, cost, safety, security and regulatory issues through research, development and demonstration. By focusing on the development of advanced nuclear technologies, NE supports the Administration’s goals of providing domestic sources of secure energy, reducing greenhouse gases, and enhancing national security.” The NE budget in 2015 was $914 million. In addition, some twenty laboratory and technical centers are connected significantly with nuclear energy and/or with nuclear weapons. The DOE budget for various US laboratories, some of which are run by private corporations, others by universities, and still others are federal, was roughly $30 billion in 2014. (Some of these laboratories and programs are quite small, others very large. See US DOE 2016a.)

The Nuclear Energy Institute has roots to several groups from the 1950s, but was founded in 1994 from the merger of the Nuclear Utility Management and Resources Council (NUMARC), the U.S. Council for Energy Awareness (USCEA), which conducted a national communications program, the American Nuclear Energy Council (ANEC), which handled governmental affairs, and the nuclear division of the Edison Electric Institute which handled issues involving used nuclear fuel management, nuclear fuel supply and the economics of nuclear energy.

Proponents and Opponents

Generally speaking, supporters of nuclear energy emphasize the facts that nuclear power will help secure US energy independence; does not produce greenhouse gases that contribute to global warming; is a proven technology whose next generation of reactors are, or will be almost inherently safe; and is crucial to provide base load for energy demand into the 21st century. They argue that NPPs operate as intended. Those who support nuclear power include such groups and individuals as utilities, manufacturers, trade associations, state and national representatives, and members of the public.

Those who oppose nuclear power, or at least call for greater circumspection concerning its further development, include such scientific organizations as the Union of Concerned Scientists (UCS), and a wide range of citizen-led ad hoc and formal groups. Opponents note that nuclear power is more costly than supporters contend, indeed has a history of cost overruns; may be risky, certainly more risky than supporters admit; they note that in the case of a catastrophic accident, people and property may be damaged, and timely evacuation will be nearly impossible; and they point out that no long-term solution for the large quantities of high level radioactive waste and spent fuel that occupy the nation's NPPs has been found. They also note the practice of siting stations near population centers may save costs for infrastructure and transmission of electricity but opens millions of consumers precisely to the risk of accidents. Finally, they observe the industry has a less stellar record of operation than industry contends.

According to one analysis, several images frame attitudes toward nuclear power. A prevailing view among proponents suggests that nuclear energy represents progress with its promise of clean energy, efficiency and "technofixes" with their implicit rejection of Luddism. An opposing position finds that nuclear technology leads to the destruction or disruption of nature. This framing plays out in media which are crucial in the construction of public understandings with their images, meanings and messages set forth in TV, newspapers and journals, cartoons, and opinion columns. (Gamson, Modigliani. 1989) The framing is directed toward a potentially confused or uneducated public, perhaps even towards those with dangerously anti-American sentiments. For example, protestors against construction of a reactor at Bodega Bay were equated by the utility PG&E with communists. (Walker, 1990). In his study of opposition to Diablo Canyon, Wills argues that antinuclear activism reflected more concerns about "about human ties with nature" than East-West competition or anger over big government. (Wills, 2006: 9).

Spencer Weart points out that in the mid-1960s American agencies and corporations made twice as many films about reactors and three times as many about safety and environment as in the preceding five years. In the 1960s roughly 40 million people attended AEC film screenings and many times more watched at home on TV. Weart writes, "The result was less to excite the public about AE than calm them. The films toned down the utopian promises of 1950s films," focusing on electrical energy rather than on "medical and agricultural fantasies." (Weart, 1988: 299) Among the AEC films of the 1950s included "Power and Promise: The Story Of Shippingport Nuclear Power Plant,"[1] "Nuclear Energy Goes Rural," "Atomic Venture," "Atomic Power Today: Service with Safety."

A shaded dualism with images of instantaneous, enormous destruction, and Frankensteinean futures vying with those of the peaceful, powerful atom as protector and as benevolent (utopian) servant characterize the period from Hiroshima to the 1960s. The rise of anti-nuclear discourse characterizes the period from the 1970s to TMI, with the hegemony of the vision of progress destroyed. While nuclear was connected to energy independence from OPEC oil, fear of proliferation led to attacks on nuclear power, notably in President Jimmy Carter's rejection of the US LMFBR. Such anti-nuclear groups raised public awareness of safety issues at the time: Friends of the Earth, Critical Mass, and the UCS. (Gamson, Modigliani. 1989)

The relatively litigious American legal and administrative system permits interveners to exert influence on the technology assessment process. Building on the anti-war and environmental movements of the 1960s, and especially since the 1970s, the establishment of the Environmental Protection Agency, the Occupational Safety and Health Administration, and other regulatory and safety bodies, many American citizens have sought to participate in the regulatory process directly through petitions and lawsuits. They have also turned to protest and the organization of NGOs to pursue their goals (see case studies on Diablo Canyon and Seabrook). At first the public enunciated little concern about atomic energy. But when the atom was tied to concerns about weapons testing and fallout, then worries grew. One poll published before 1962 (in 1956) showed 69% of Americans had no fear of having a plant located in their community. (Erskine, 1963)

The picture changed with TMI and Chernobyl, with ubiquitous visions, especially for the Chernobyl accident, revealing great and persistent dangers. The authors conclude that media discourse provides

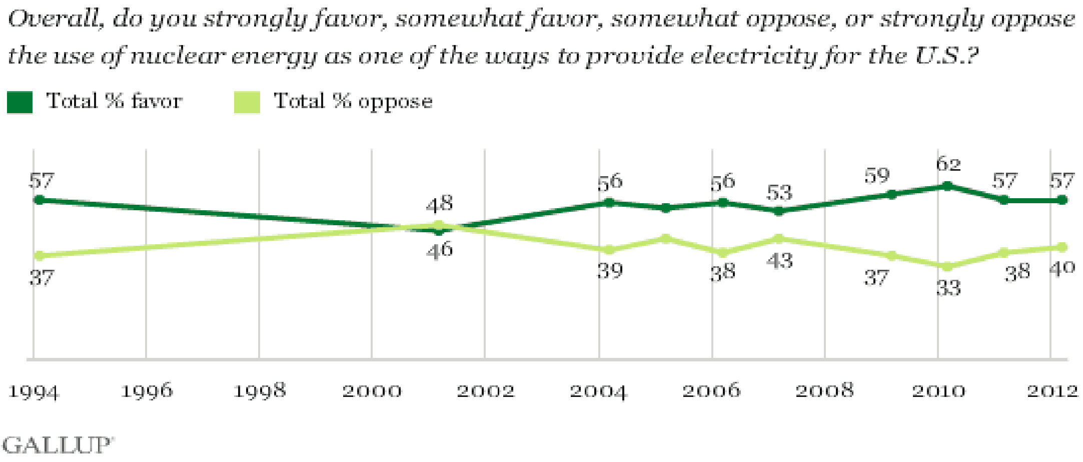
> …an essential context for understanding the formation of public opinion on nuclear power. More specifically, it helps to account for such survey results as the decline in support for nuclear power before Three Mile Island, a rebound after a burst of media publicity has died out, the gap between general support for nuclear power and support for a plant in one's own community, and the changed relationship of age to support for nuclear power from 1950 to the present. (p. 1)

A number of NGOs have engaged in protest against nuclear power, many of which have multiple concerns and foci: the Sierra Club, the Riverkeeper, the Union of Concerned Scientists (UCS), the latter “founded in 1969 by scientists and students at the Massachusetts Institute of Technology.” According to UCS, “That year, the Vietnam War was at its height and Cleveland’s heavily polluted Cuyahoga River had caught fire. Appalled at how the U.S. government was misusing science, the UCS founders drafted a statement calling for scientific research to be directed away from military technologies and toward solving pressing environmental and social problems.”(UCS, n. d.) For their part, the nuclear industry and US government bodies have sought to engage the public over the benefits and safety of nuclear.

The investigative arm of the Congress, the Office of Technology Assessment (OTA) that might have provided Congress with important, unbiased input on energy policy generally and nuclear power and climate change specifically, was destroyed by Speaker Newt Gingrich in part because of its independence and objectivity. During its years of operation (1972 – 1995) OTA studied over 750 studies that begged for objective, non-partisan critical understanding, many in the nuclear area. In 1984 OTA published *Nuclear Power in an Age of Uncertainty* that considered “Public Attitudes Toward Nuclear Power.” The study noted that “public attitudes toward nuclear power have become increasingly negative over the past two decades, with the most recent polls indicating that a slight majority of Americans opposes further construction of reactors.” In the 1950s pollsters hardly studied the issue, while in the 1960s several opinion polls noted that less than a quarter of the public opposed nuclear power. In the 1970s substantial majorities of the public still favored nuclear power, even as anti-nuclear referenda appeared on ballots in eight States. The accident at TMI led to a sudden decease in the percentage of people who had been in favor of or uncertain about continued construction of reactors, with the percentage opposed increasing. Polls since mid-1982 indicated a slow erosion in support for nuclear power with over 50 percent opposed, and a large majority opposed to the construction of new plants in or near their communities. Nuclear was even less appealing than offshore oil drilling and coal plants, nuclear is now the least favored alternative. In spite of a majority finding nuclear power as potentially unsafe, many people saw it as a solution to the country's long-term energy problems, and the majority rejected a halt to new construction or a permanent shutdown of all operating reactors. (OTA, 1984: chapter 8)

According to the Gallup polling organization, nuclear power seemed fully to recover its standing among citizens in the 1990s and 2000s, with those in support of maintaining nuclear energy in a strong majority, even after the Fukushima disaster until 2016. (Newport, 2012, Reffkin, 2016). See table 1.

Table 1. Support for Nuclear Power Among US Citizens, 1994-2012



Source: (Newport. 2012.)

Media actors – those people who work for or direct newspapers, radio and television, press centers and public information offices, films and documentaries – have an important presence in the history of nuclear power in the US. They have been central in informing the public and shaping attitudes at the early stages of the "peaceful atom" (Boyer, 1985; Weart, 1988); in reporting on the history of the industry, licensing, and regulation; and in presenting particular messages from industry, government, and NGOs. One could argue that the ultimate “openness” of the US system enables a high degree of public participation in the technology assessment process and enables usually better outcomes in the technologies promoted and defused, including nuclear technologies.

2. Showcase: Early Demonstration Projects: From Nuclear Utopianism to Public Concern

Against this regulatory and financial backdrop, the construction of nuclear power stations moved forward in the United States. Given its mandate, the AEC worked to promote a number of demonstration plants that indicated the promise of nuclear power. Along with successes at Shippingport, there were great failures at Fermi, Bodega Bay, and Ravenswood.

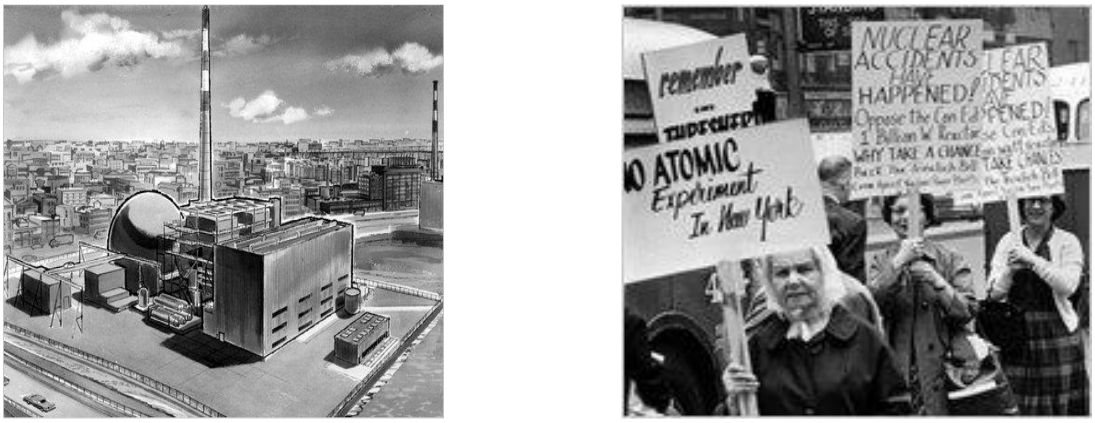
The first commercial NPP in the United States to use nuclear energy was the Shippingport Atomic Power Station of the Department of Energy and the Duquesne Light Company, not far from Pittsburgh on the Ohio River. In a dramatic high-tech display, ground was broken in 1954 during dedication ceremonies by President Dwight D. Eisenhower, who also opened it on May 26, 1958, as part of his “Atoms for Peace” program. The reactor plant was designed by the Westinghouse Electric Corporation in cooperation with the Division of Naval Reactors of the Atomic Energy Commission, as a large-scale light water reactor for a proposed aircraft carrier (Hewlett, Duncan, 1974); Westinghouse rapidly became a world leader in nuclear power.

The first power at Shippingport was produced on December 18, 1957, and was fed into the grid for the Pittsburgh area; it was 68,000 kW – or one-sixteenth the size of today’s reactors. The design of the power plant was again altered in 1977, when the core was changed to a light water breeder reactor (LWBR). A breeder reactor uses both thorium and uranium as a fuel source. As the reactor consumes uranium, it produces more uranium from thorium as a by-product. The reactor is designed to produce more uranium than it uses, allowing the plant to use thorium, which is a cheaper and more abundant fuel source. (ASME, n. d.)

Another early project, Dresden 1, the first privately-financed NPP, was activated in 1960 and retired in 1978. It is a GE BWR (like those at Fukushima), and it was fraught with operating problems. Operating since 1970 are Dresden units 2 and 3 with GE BWRs. Its licenses were extended in 2004 from 40 to 60 years. Tritium leaks into surrounding groundwater plague the NPP.(US NRC, c.2004) Between the 1970s and 1996, Dresden was fined $1.6 million for 25 incidents.

Ravenswood, Queens, NY, 1962

In the early years of nuclear power, utilities and regulators rarely gave a second thought to the possibility of siting an NPP in an urban area. The goal was to build close to demand and keep transmission and infrastructure costs down. Yet “organized resistance” to nuclear power plants emerged in New York, California and elsewhere over plans for such NPPs. One of the first controversies concerned the application of the Consolidated Edison (ConEd), Inc. – one of the largest investor-owned electrical companies in the US that provides electricity to New York City, to build a 1,000 MW NPP in Ravenswood, Queens, only two miles from the UN. A former chairman of the AEC, David Lilienthal, said, “I would not dream of living in the borough of Queens if there were a large atomic power plant in that region, because there is an alternative — a conventional thermal power plant as to which there are no risks.” The group “CANPOP” -- Committee Against Nuclear Power Plants -- formed to protest. ConEd’s Ravenswood application made the AEC consider more systematically whether to permit the construction of nuclear power plants in large cities. Eventually ConEd withdrew its application for a construction permit. (Mazuzan, 1986)


remember
NO ATOMIC Experiment In New York
NUCLEAR ACCIDENTS HAVE HAPPENED!
WHY TAKE A CHANCE
TAKE CHANCES

(l) ConEd’s proposed Ravenswood NPP on the Queens waterfront; (r) the Ravenswood application to the AEC drew significant protest.

Bodega Bay

Another early project that triggered anti-nuclear protest – and demonstrated the AEC's weaknesses in assessing risk and safety without internal experts – was the request of Pacific Gas and Electric Company (PG&E) in 1963 for a permit to build a 340 MW nuclear plant at Bodega Head, about 50 miles north of San Francisco. PG&E originally thought of a thermal station but jumped on the nuclear wagon to meet regional rapid growth in population and energy demand that required new capacity of some sort. Opponents initially opposed the plan to preserve the natural beauty of the oceanfront site for parkland. They uncovered a more serious issue that ought to have disqualified the site: the discovery of a geological fault not far from the station. PG&E for its part had already begun excavation of the site. The Bodega Bay NPP proposal, therefore, was crucially important in placing before the AEC the issue of earthquakes and reactor safety. Eventually, since the AEC could not approve the site as seismically stable with certainty, PG&E withdrew its application.

Public involvement was crucial here. By December 1963 the Northern California Association to Preserve Bodega Head and Harbor had grown to about 800 members who opposed the station. Many people believe its success had much to do with the efforts of its executive secretary, David Pesonen, a man who wrote extensively, including an editorial critical of Price-Anderson in *New Republic* in 1965. Pesonen worked at the Sierra Club and represented it at hearings on Bodega Bay at the California Public Utilities Commission. Personen noted that the reactor would be only a few hundred feet of the San Andreas fault, and even PG&E experts admitted that a major earthquake like the 1906 San Francisco earthquake was possible within a century. Yet those experts believed that they could build an NPP to withstand an earthquake of major proportions and insisted on the "absence of active faults." (Walker, 1990) As protests grew, PG&E played hardball accusing the association of being a communist front organization.

PG&E developed a reactor design "on a base of special sand and allowed three feet of clearance between the reactor's walls and the side of the hole it would sit in." Shockingly, until this time the AEC had no seismologists on staff. The March 1964 Alaska earthquake, at 8.6 the largest in North America ever recorded, created more discussion and concern about the design. Finally, in October 1964, the AEC released its findings that PG&E had tried to engineer suitable protection in reactor containment structure in the event of an earthquake, but that the designs were unproved and untested, and PG&E withdrew its application and canceled plans for the plant, turning instead to a site closer to Los Angeles for its Diablo Canyon NPP.(Walker, 1990; Pesonen, 2013)

Indian Point NPP

Once the AEC turned down ConEd's request to build an NPP in Queens, NYC, ConEd proceed with plans to build at Indian Point, on the Hudson River, only 65 kilometers by car from Manhattan and the largest metropolitan area in the US – and 50 kilometers as the crow flies. After the Fukushima disaster, the US Embassy recommended that all Americans within 50 miles leave the area. If the same parameters were used in a meltdown accident at Indian Point, 20 million people might have to leave – an impossibility. The population density around the station is 2,100/square mile, the highest for any US NPP.

Indian Point is probably the most poorly operated and dangerous NPP in the US as has been documented extensively in the *New York Times* (New York Times, 1983). From initial planning in the early 1950s to construction in the 1960s, to the shut down of unit one, to cost overruns even before construction, to the ongoing farcically and tragically unsafe operation of units 2 and 3 – two 1,000 MW Westinghouse PWRs – that Entergy, which bought the plant from ConEd, has petitioned to keep open to 2029 for one unit and 2031 for the other, Indian Point is miserable way to run a business, let alone an NPP. Governor Andrew Cuomo wants to close Indian Point.

Recent accidents – some of which appear to be caused by malfeasance – give a sense of the serious problems that continue to plague the Indian Point NPP. (UCS, c.2015) In May 2015, an electrical transformer at Unit 3 exploded, causing water to flood a room where electrical distribution panels are housed, and pouring 3,000 gallons of oil into the Hudson River; threatening a station blackout. In February 2016 radiation levels at three monitoring wells around the plant spiked by 65,000%, although the power company claimed there was no danger to the public. In March 2016, during refueling, a breaker tripped and cut power in one of the reactors; when the diesel generators kicked in, they died while trying to restart the first electrical system. Fortunately a second backup worked. Also in March, a special inspection of unit 2 found that 27.5% of the stainless steel bolts needed to channel cooling water through active nuclear fuel rods were broken, distorted or "missing" entirely! A series of unplanned shutdowns plague the station. Finally, the heated effluent water – up to 2.5 billion gallons a day – kills about 1 billion fish and other aquatic organisms a year. (Thielman, 2016)

Reactors 2 and 3 remain open in part because of a regulatory failing: so many complaints called “contentions” have been filed with the NRC that the station is allowed to operate until it can respond to all the grievances as part of its relicensing process. Thus, three weeks after the water leak, the NRC approved Entergy’s request, made several years prior, that it be allowed to perform a comprehensive leak test every 15 years, rather than every 10. According to Edwin Lyman, a senior scientist with the Union of Concerned Scientists, the license-renewal process itself risks public safety in that it “was designed to limit the scope that could be considered, specifically the ability of the public to intervene” by requiring stations to address “contentions” by showing the operator has a plan to correct a specific problem. (Thielman, 2016)

The significant number of serious accidents and “contentions” led an NGO dedicated to the health and safety of the Hudson River, Riverkeeper, to push to shut down Indian Point NPP. Riverkeeper offered ten reasons to close Indian Point including seismic risks, exemptions for safety rules, a weak evacuation plan, a threat to NYC’s water supply. A series of incidents – and major accidents – which indicates the challenges faced in mastering nuclear technology, assuring the public about safety, and the risks that are revealed in station operation that may begin from the mundane and move quickly to a near catastrophe.

Brown’s Ferry, Alabama (1975)

An accident at Brown’s Ferry in 1975 indicated the precarious nature of public safety in such a regulatory environment. A fire at Brown’s Ferry took hours to put out, showed fire hazards everywhere, but no fire suppression equipment, and even malfunctioning emergency telephones, all of which came close to creating a LOCA.

At noon on March 22, 1975, both Browns Ferry Units 1 and 2 at the NPP were operating at full power (1,100 MWe each) to the Tennessee Valley Authority. (Comey, 1976) Two electricians were trying to seal air leaks in the cable spreading room below the control room, through which the electrical cables that control the two reactors run, and the reactor building. They used spongy foam rubber to seal the leaks. They used candles to determine whether or not the leaks had been successfully plugged -- by observing how the flame was fluttered by escaping air. The electrical engineer put the candle too close to the foam rubber, and it burst into flame. He tried "to extinguish the fire by beating out the flames with a flashlight and by smothering [it] with rags." The other worker returned with a fire extinguisher, and it failed to stop the flame, too. They went to the reactor building to use extinguishers from the opposite side. They notified the shift engineer only 19 minutes later, by which time thick, dense smoke hindered efforts. The control panel began to malfunction as did Unit 1 pumps. After the power level on the Unit 1 reactor began to drop inexplicably, the operator started to reduce the flow of the reactor's operating pumps; when the pumps suddenly quit at 12:51, he finally shut the reactor down by inserting the control rods. That is, Unit 1 was scrammed at 31 minutes and unit 2 at 40 minutes.

More Detail on the Tragedy of Mistakes

At Brown's Ferry Unit 1, a March 22, 1975, fire disabled a large number of engineered safety systems at the plant, including the entire emergency core cooling system (ECCS) on Unit 1, and almost resulted in a meltdown accident. Beginning at 12:55, the electrical supply was lost both to control and power the ECCS core spray system was lost; the low-pressure ECCS was lost; the reactor core isolation cooling system was lost; and most of the instrumentation which tells the control room what is going on in the reactor was lost. Some of the shutdown equipment began failing on Unit 2, and the high-pressure ECCS was lost at 1:45 pm. Control over the reactor relief valves was lost at 1:20 pm and not restored until 2:15 pm, at which time the reactor was depressurized by using the relief valves and brought under control.

With all ECCS systems lost, decay heat in the reactor core forced water temperature to rise and core pressure rose to the relief valve set points. In its report on the cause of the fire, the TVA stated: "The material ignited by the candle flame was resilient polyurethane foam. Once the foam was ignited, the flame spread very rapidly. After the first application of the CO_2, the fire had spread through to the reactor building side of the penetration. Once ignited, the resilient polyurethane foam splattered as it burned. After the second extinguisher was applied, there was a roaring sound from the fire and a blowtorch effect due to the airflow through the penetration." The report continued, "The airflow through the penetration pulled the material from discharging fire extinguishers through the penetration into the reactor building. Dry chemicals would extinguish the flames, but the flame would start back up." (Tennessee Valley Authority, 1975: 14-15)

The fire department was called only 49 minutes after ignition, it arrived 85 minutes after ignition, but was not given permission to use water, only dry suppression, and it was not admitted to the station for 15 minutes. Almost seven hours after ignition the Athens Fire Department finally received permission to use water but interior hose line and nozzle was inadequate to reach the burning cable trays. About 1,815 kg of PVC burned releasing 645 kg of toxic chloride gases into the reactor building.

As the NRC report on the incident noted,

> The Browns Ferry Nuclear Plant Emergency Procedure lists two different telephone numbers to be used in reporting a fire, one in a table of emergency numbers and the second in a test of the procedure. The appropriate number (299) is the one in the test; dialing this number automatically sounds the fire alarm and rings the Unit 1 operator's telephone. The Emergency Procedure was not followed by those involved when reporting the fire. The construction workers first attempted to extinguish the fire, whereas the procedure specifies that the fire alarm be sounded first. The guard reporting the fire telephoned the shift engineer's office rather than calling either of the numbers listed in the procedure. (Comey, 1976)

The use of polyurethane foams to plug leaks and polyvinyl chloride cable was a mistake in itself because the nature of the material. Also, the “lack of qualified, experienced, fire protection staffing contributed to the conditions which resulted in a direct loss of $10 million and an indirect loss of $30 million related to business interruption.” “Poor design, fire detection and fire suppression provided only on a partial or limited basis; use of polyurethane; no management interest in fire safety” all of which nearly led to a meltdown. (Pryor, 1977)

3. Events

The following five events largely cover the history of commercialized nuclear power in the United States, from nascent efforts of the AEC to push nuclear power in the 1950s, to the efforts of the NRC to regulate and ensure the safety of a mature industry in the twenty-first century. The latter is occurring against the backdrop of aging reactors yet determination of industry and regulators to extend the operating licenses of NPPs. Indeed, in December 2016 two US Senators called for consideration of ways to extend licenses within safety parameters to permit operation to 60 and up to 80 years as a way to slow global warming. (Lamar Alexander, Sheldon Whitehouse, 2016)

The events also permit analysis of the evolution of protest about nuclear power, from concern within the industry about the nature of risks, accident probabilities, and appropriate regulatory framework to ensure safe operation, to public protest over siting, emergency evacuation, and costs. The events similarly permit examination of the role of experts in technology assessment in democratic society, as well as the rights of citizens to intervene in legal and regulatory processes. These events permit fuller comprehension of the evolving attitude of the public toward nuclear power and of the secrecy that sometimes characterized the deliberations of the industry and its regulators. The events include two mass public protests. Finally, the events include the Three Mile Island accident and an effort to understand both the cause of the accident and the nature of the response of local, state and national emergency response personnel and regulators.

3.1. Event 1: Licensing and Operation of Enrico Fermi (Detroit) Breeder Reactor

The Enrico Fermi Atomic Power Plant, Unit 1, located in Monroe County, Michigan, near Detroit, was an LMFBR, designed for 430 MW, although the maximum reactor power with the first core loading was 200 MW. It suffered a meltdown in 1966 that made the reactor inoperable and endangered millions of people. The accident was kept secret at the time.

The Atomic Energy Commission, encouraging at every step the entry of a nascent nuclear power industry, facilitated the licensing of "Enrico Fermi," although the LMFBR, as an industrial prototype, was untested. In January 1955 the AEC announced a Power Demonstration Reactor Program, "designed to open the way for American industry to develop, fabricate, construct, and operate experimental reactors." (Mazuzan, 1982: 343) Prior to the construction and licensing of "Enrico Fermi" the US Congress passed the 1957 Price-Anderson Act to limit the liability of the nuclear industry to $560 million. (Bangs, 1961; Pesonen, 1965). The result was a rush to bring such NPPs into operation as Shippingport, PA (1958), Dresden (1960), and Fermi (1966).

Detroit Edison formed the Power Reactor Development Company (PRDC) to move Fermi ahead. In the late 1950s the United Auto Workers (UAW) union brought a lawsuit to halt construction because of safety concerns, and lost eventually in the US Supreme Court, with 7 of the 9 judges siding with PRDC. Other public concern was limited by AEC secrecy. (US SC, 1961)

Main Actors	The AEC, through its promotional activities, provision of materials, equipment, knowledge and uranium fuel; industry, through a not-for-profit corporation, the Power Reactor Development Company (PRDC) that sought to build a breeder reactor near Detroit; workers associated with the construction of the reactors and their union representatives; media reporting on the Enrico Fermi reactor; and the courts who evaluated whether the AEC and PRDC had moved from permit to construction according to correct administrative procedures were involved in this event. Through less-than-opaque review procedures and secrecy, the AEC kept its review of safety and other issues out of public scrutiny.
When and where did it take place? Change over time?	1950s (reactor first proposed and construction begins) to operation and meltdown in 1966 to closure in 1973.
What type of process was it? How did this change over time?	In the 1950s and 1960s the regulatory process evolved under the AEC's mandate to promote nuclear power and encourage the private sector to join in. Through less-than-opaque review procedures and secrecy, the AEC kept its review of safety and other issues out of public scrutiny. PRDC officials never lacked confidence in their reactor program.
Transnational concerns?	Transnational concerns played no role in this event except insofar as researchers in national laboratories working on LMFBRs were interested in similar research abroad, notably in Russia.
Regulators, trust, procedures?	The public was belatedly informed about the meltdown that occurred at Fermi in 1966; regulators did not observe their responsibilities to regulate; there were no emergency procedures to speak of.
Public-nuclear interactions?	The Enrico Fermi licensing process with court intervention may be the first time in US history that public individuals began to oppose nuclear power. The head of the UAW Walter Reuther became convinced that the Enrico Fermi NPP would endanger Detroit, the auto industry and

	auto workers, and brought a lawsuit against the station. Leo Goodman, a union activist who had helped to organize nuclear workers, convinced Reuther to oppose the stations's construction.
Outcome	Although the UAW lost the court case concerning Fermi, their legal activities helped establish strategies and procedures for future intervention. The Fermi accident did not change AEC regulatory procedures or increase openness. This would be some time in coming, since AEC commissioners still believed in the technology and were confident in their procedures.

The Enrico Fermi Reactor primary system was filled with sodium in December of 1960 and criticality was achieved in August 1963. Enrico Fermi 1 experienced a meltdown in 1966 due to a problem that no one had detected that dated to 1959 in the reactor core at which time there were only 4 stations operating in US and there was no experience on which to base response of plant, state, or federal personnel, nor any procedures to manage accidents, and no one in the control room had any sense what occurred. That sense developed only years later after dangerous, careful and expensive investigation.

The LMFBR had a long history starting with the research of Walter Zinn and others at EBR-1 at NTL in Arco, Idaho, in 1951 that indicated both the promise and potential safety risks associated with breeder reactors. Detroit Edison directors believed that the private sector should build and run the next breeders, and by 1952 they created a not-for-profit division, the Power Demonstration Reactor Corporation (PDRC) to look into building a reactor and entering the nuclear age. As John Fuller writes,

The developers of the Fermi breeder reactor were very sincere, diligent, and highly qualified individuals to whom the safety of the reactor was paramount. Extreme care was taken to insure against the possibility of a serious accident occurring. The scientists involved were most confident that they had covered all possible problem areas. They had built safeguards on top of safeguards. Yet in spite of the precautions in the design and construction of the Fermi reactor, and in spite of the reassurances by the scientists that a serious accident could not happen, one did occur. (Fuller, 1975: 54). In fact the LMFBRs on which Fermi was based were very small scale and worked poorly, and there had been a series of accidents and incidents with all sorts of reactors in the industry. Theoretical safety in design was clearly different from practical safety in operation.

Incomplete data and uncertainty led the Advisory Committee on Reactor Safety (ACRS) in June 1956 to issue a letter on the Fermi to the AEC: “The Committee as a whole was not satisfied with the evidence presented that no credible supercriticality accident resulting from meltdown could breach the container.” The ACRS recommended measures “to insure subcritical distribution of melted fuel and to assure that free fall of core parts cannot reassemble a critical mass suddenly.” (ACRS, 1970?: 2) Indeed, the ACRS, “was not satisfied with the evidence presented that no credible supercriticality accident resulting from meltdown could breach the container. It is felt that a more extensive theoretical and experimental program to examine all the possibilities needs to be established and pursued vigorously…"(Fuller: 54) Even with insufficient information and experience, in August the AEC still issued a construction permit to PRDC to build proximate to a major urban center. To preclude controversy, Commission Lewis Strauss marked the ACRS letter “administratively confidential,” and went before the US Congress to announce groundbreaking for the construction, not to indicate any circumspection. (Fuller: 56)

In 1959 the AFL-CIO (American Federation of Labor-Council of Industrial Organizations) under Walter Reuther filed a brief that the US Court of Appeals upheld in 1960 that the construction permit for the Enrico Fermi LMFBR plant was illegal and that building would have to stop within fifteen days. But the US Supreme Court quickly overturned that decision, 7-2, declaring that the AEC had been within its rights in permitting the Fermi reactor to be built and that final construction could proceed unhindered. In the majority decision, Justice Brennan stated that the AEC had found “reasonable assurance for present purposes, and that is enough to satisfy the arguments of law,” and that a step-by-step process of licensing to operation ensured safety. In the minority opinion Justices Black and Douglas referred to the AEC's own safety committee report in which they wrote, “Plainly these are not findings that the safety standards have been met. They presuppose . . .that safety findings can be made after the construction a finished. But when that point is reached, when millions have been invested, the momentum is on the side of the applicant, not on the side of the public.”(US SC, 1961)

The Fermi Reactor went through a series of tests, achieving criticality in 1965. But subsequent testing through 1965 and 1966 reviewed difficulties in controlling power levels in the reactor, temperatures in the sodium coolant flowing through fuel assemblies were higher than normal, and fuel assemblies were exhibiting abnormally high temperatures. Finally, on October 5, 1966*,* the reactor suffered a meltdown, radiation entered the building triggering alarms, and operators determined only 10 minutes later to scram the reactor manually – the reactor had failed to shut down automatically. Subsequent examination of the fuel assemblies revealed that melting had occurred in two while two others were damaged from overheating. Expensive and dangerous investigation determined that two of the six zirconium pieces added to the core inlet plenum in 1959 had broken free and blocked cooling flow through the fuel assemblies, this had limited flow to about three percent of normal for the two assemblies that experienced melting. (ACRS: 2) However, the PRDC determined that no abnormal releases to the environment occurred. Three years and nine months later, Detroit Edison restarted Fermi 1. The UCS termed the AEC's role following the accident "more like that of a hall monitor" for its passive review, occasional inspections, and no effort to audit the recovery effort, let along learn from the accident. (UCS. c.1970: 4) In November 1972, having failed to operate the unit at any level close to specification, PRCD determined to decommission Fermi 1, the fuel and blanket subassemblies were shipped offsite in 1973, and radioactive sodium was stored on site until 1984.

It should be noted that only Russia has ongoing experience with a commercial LMFBR, the BN-800, at the Belioarsk NPP, in Zarechnyi, Russia. French, Japanese and Chinese industrial breeders have been shelved or lag. See Russian and French country reports.

3.2. Event 2: Licensing and Protest over Diablo Canyon (California) NPP and the Abalone Alliance Protests

In the early 1960s representatives of the California utility PG&E announced plans to construct a nuclear power plant in an undeveloped area on the California coast, apparently seeing a perfect blending of the machine and the pastoral. Not for a minute did they recognize the cognitive disjunction of the "machine in the garden." (Winner, 1986; Meehan, 1984) They settled on Diablo Canyon with a gorgeous view of the Pacific Ocean. The building of this NPP on an active earthquake fault was characterized by substantial cost overruns -- similar to those which have characterized the construction of virtually all reactors throughout the world. Utility spokesmen initially estimated costs at $400 million for two units, but by 1976 the bill had risen to $1.2 billion. When unit 1 opened on May 7, 1985, and unit two on March 18, 1987, the total cost of the plant was $5.52 billion. Construction and licensing provoked mass protest among thousands of activists. These activists, the Abalone Alliance, came in thousands to engage in non-violent actions to halt the station. Diablo Canyon will be closed down by 2025.

Main Actors	AEC, NGOs (Friends of the Earth, Abalone Alliance, other local and state groups), NGOs (Union of Concerned Scientists) utilities (PG&E), media (newspapers), 1,500 NPP staff and workers
When and where did it take place? Change over time?	1960s-2010s Beginning in the 1960s when PG&E applied for permits and began construction, through operation in the Diablo Canyon in the 1980s, this NPP was plagued by stops and starts, legal actions and massive protests, lack of openness about the potential risks of construction at this site, especially concerning earthquake faults, and massive cost overruns.After initially asking to extend the license for 20 years, PG&E has agreed to close Diablo Canyon by 2025.
Communication	Investigation by local journalists and activists reveal that PG&E had obfuscated the true state of affairs regarding seismic safety of the NPP.
Alliances among actors?	Anti-nuclear groups worked together. Eventually roughly 60 anti-nuclear groups and 30,000 people came together in protest.
Transnational concerns?	Transnational concerns played little role here.
Regulators, trust, procedures?	The regulators (AEC → NRC) lost the trust of the people. The NRC seemed to put industry interests ahead of public concerns that were based on accurate evaluation of seismic data and risk, even though at Bodega Bay in the 1960s (NPP rejected by AEC, proposed by PG&E, north of San Francisco, see country report) forced regulators to include seismic data in a standardized licensing process.
Public-nuclear interactions?	At this time (1970s) it became clear through an FOIA request from Friends of the Earth that the AEC had actually suppressed publication of a 1964 update of WASH-740 (1957), a reactor safety study, that estimated a worst-case scenario accident leading to at least 3,400 deaths and $7 billion of property damage, well over the amounts covered by the indemnities of the Price-Anderson Act (1957) with a limit on liability of $560 million. Over time, protests became more widespread. They continued into the twenty-first century, especially as the UCS pushed to have the NRC recognize the danger of further operation.
Resolution	In 2016 PG&E, the State of California and NRC agreed the station should be closed down.
Video	1981 Abalone Coalition Occupation of Diablo Canyon, https://www.youtube.com/watch?v=MPBtwfYcy-M (Irving, 1981)

Diablo Canyon Narrative

Diablo Canyon Nuclear Power Plant is owned and operated by Pacific Gas and Electric (PG&E). The utility applied to the Nuclear Regulatory Commission (NRC) to renew s two current operating licenses for 20 more years, which would have extended operations from 2024 and 2025 to 2044 and 2045. "This facility, next to the Chernobyl disaster is probably the most controversial nuclear facility in the world due to intense public opposition," states the Abalone Alliance in its history of the plant. However, PG&E has agreed to close the station by 2025.

While selecting the site in the early 1960s, only in 1969 did geologists discover the nearby Hosgri earthquake fault. In October 1981 the *San Jose Mercury* revealed the fault was in the ocean only 4 kilometres from the reactors, and that PG&E "knew about the fault for at least a year before telling the public and the Atomic Energy Commission." According to a U. S. Geological Survey report, the station's seismic design could not withstand the maximum potential quake possible, and this led to retrofitting and upgrading. The NRC licensed the facility after redesign. (Sneed)

In the 1970s it became clear through an FOIA (Freedom of Information Act) request from Friends of the Earth that the AEC had actually suppressed publication of a 1964 update of WASH-740 (US AEC, 1957), a reactor safety study that estimated a worst-case scenario accident leading to at least 3,400 deaths and $7 billion of property damage, well over the amounts covered by the indemnities of the Price-Anderson Act with a limit on liability of $560 million.

The response of public relations representatives at Diablo Canyon to Fukushima was to claim that their reactors were nearly 30 meters above the ocean, with a facility designed to withstand a 7.5 quake in a 6.5 zone, with stored fresh water and diesel generators for emergency operation and cooling. (Sneed, 2014) But what if the non-design 8.0 quake occurred? Will this become a natural disaster? The 1979 movie, "The China Syndrome," released just two weeks before the accident at Three Mile Island NPP, suggests that profit-seeking utilities may not understand the full complexity of reactors and suggests what might happen in a melt-down accident at Diablo Canyon or elsewhere.

Diablo Canyon Units 1 and 2

	Unit 1	Unit 2
PG&E applied for construction permit	Jan. 16, 1967	June 28, 1968
AEC issued construction permit	April 23, 1968	Dec. 9, 1970
NRC issued operating license	Nov. 2, 1984	Aug. 26, 1985

One of the first public protests against nuclear power gelled around the Diablo Canyon station. The Abalone Alliance (1977-1985) took its name from the multitudinous red abalone massacred in Diablo Canyon in 1974 when the utility carried out a hot flush of the reactor unit's plumbing. The Alliance, "a loose coalition of 60 anti-nuke organizations, staged blockades and occupations at the reactor site. Nearly two thousand people were arrested during a two-week blockade in 1981, making this the largest number arrested at an anti-nuclear protest in the United States. Perhaps as many as 30,000 protestors descended on the site. (Rogers, 1981) The Alliance sought not only demonstrations, but resistance to ensure that Diablo Canyon never operated as a nuclear power station. Opposition here –at the Bodega Bay plant north of San Francisco (not built) – and at Seabrook – required that protestors became technologically sophisticated in identifying risk factors and in understanding the law and administrative procedures needed to pursue opposition.

Abalone Alliance members worried about faulty and inflated projections for nuclear power, the economic cost of NPPs, the lack of democratic possibilities surrounding governance of nuclear power, the direct relationship between civilian and military nuclear power, the dangers of theft and sabotage, and the short and long terms dangers of NPP. (Direct Action, 1981) As for the 1981 action:

> In 1981, the Diablo Canyon nuclear power plant — being constructed by PG&E astride an active earthquake fault — was nearing completion. A 1979 protest drew attention to the project and resulted in over 100 arrests. In summer 1981, Abalone Alliance, a statewide network of affinity groups and community organizations, called for a blockade of the site. Hundreds of people responded. An action encampment was set up near the site, and over

> the course of several weeks the protest led to over 2000 arrests. Near the end of the action, whistle-blowers within PG&E alerted the media that earthquake safety plans were seriously flawed. This information delayed the plant's opening by several years. Diablo Canyon was finally licensed in 1984, after hundreds more citizen arrests, which have continued to this day. (Direct Action)

Such other groups as Mothers for Peace, Friends of the Earth, and Redwood Alliance were inspired to derail nuclear power as unsafe, undemocratic, and expensive. (Direct Action, 1981)

The licensing of the Diablo Canyon Nuclear Power Station revealed the ad hoc nature of the AEC and NRC's treatment of seismic characteristics in adjudicating safety concerns and points to why many citizens do not trust either the NRC or the utilities. The rulings and evaluations indicated the difficult effort to balance the accepted need for power generation with public concerns and safety.

In the effort of PG&E to extend its license on Diablo Canyon, the utility

> …informed the Nuclear Regulatory Commission (NRC) about a newly discovered fault offshore from its Diablo Canyon nuclear plant that could cause more ground motion during an earthquake than the plant was designed to withstand. In other words, there was a gap between seismic protection levels of the plant and the seismic threat levels it faced. This seismic shift places Diablo Canyon's two aging reactors literally and figuratively on shaky ground. If an earthquake occurs, it may result in more damage than the nuclear plant can withstand, with dire consequences for tens of thousands of Californians. (UCS, 2013)

The NRC, according to the UCS, put financial concerns ahead of safety ones. In a 2013 study, the UCS described "the federal requirements governing seismic risks at nuclear power plants, the regulatory requirements specifically applied to Diablo Canyon, the identified seismic hazards that may exceed the mandated seismic protection levels, and the precedents at nuclear facilities in California and elsewhere in the United States in which the NRC took steps to protect people from undue risks—in other words, the measures the NRC is now sidestepping at Diablo Canyon." By 2013 the NRC had established clear procedures, standards, and guidelines to follow which the UCS study indicated were not being followed in the case of Diablo Canyon. (UCS, 2013)

PG&E had applied for licenses to extend operating lifetime Diablo Canyon, but in 2016 agreed with the state of California to close the reactors by 2025, in spite of industry claims that the station contributes about $1 billion annually to the local economy and is safe to operate. The utility also agreed to invest in energy efficiency, renewable power and electricity storage to offset the power that will no longer be produced by the nuclear plant. The closure means there will be no more NPPs operating in California.

3.3. Event 3: Three Mile Island, Pennsylvania, 1979

The Three Mile Island (TMI) accident was a partial nuclear meltdown in reactor unit 2 on March 28, 1979, near Harrisburg, Pennsylvania, and the most significant accident in US history. The accident revealed weaknesses in NRC regulatory powers and supervision, the slow response of federal and state agencies to safety issues, and a lack of understanding and trust among the public. After the accident, a commission under Kemmeny, analyzed the cause of the accident and response of station personnel, state and national officials, and the role of the NRC, especially its poor oversight, and the weak safety culture this permitted among industry and operators. The Kemmeny Report led to increased regulatory powers and a renewed safety philosophy among NRC staff and administrators.

Main Actors	Environmental Protection Agency, the Department of Health, Education and Welfare (now Health and Human Services), the Department of Energy, and the Commonwealth of Pennsylvania; the NRC; Metropolitan Edison Company (operator); General Public Utilities (owner); the White; farmers; local Harrisburg residents?
When and where did it take place? Change over time?	March 28, 1979, partial meltdown, government and utility response, and Kemmeny study by the end of 1979.
What type of process was it? How did this change overtime?	Partial reactor meltdown.
Alliances among actors?	State officials, federal officials, the utility and operator came together to ensure public safety, but also whitewashed the accident.
Transnational concerns?	Led to worry among nuclear officials and promoters around the world. Soviets contended “it cannot happen here.”

Regulators, trust, procedures?	The TMI accident revealed inadequate NRC supervision of the nuclear industry and even inadequate understanding among operators how to handle an emergency situation. The accident led to criticism of the NRC, and to it gaining increased regulatory and supervisory powers.
Public-nuclear interactions?	Many people now believe that government's failure to acknowledge the full scope of the disaster continues in the underestimation of risks posed by a new generation of nuclear power plants. Others believe the absence of subsequent significant accidents reveals the safety of NPPs in the US. There have been no continued protests over TMI. For further information on the public response to TMI, see the rich eyewitness accounts in the Dickinson College library archives. (Three Mile Island Archives)
Impact	According to many sources, a “tense, sometimes terrifying week… followed,” marked by official confusion and "surreal" misstatements about the crisis's severity. It did not help that movie theaters nationwide were showing the movie "China Syndrome" about a nuclear plant meltdown. The industry lost credibility. There were no new construction starts for twenty years.
Video	(*New York Times*. 2014). “Nuclear Power's Promise and Peril,” Documentary on TMI at https://www.youtube.com/watch?v=_0P9S4F4KpQ

TMI had two PWRs, one at 800 MWe that began operation in 1974. Industry claims it remains one of the best-performing units in USA. Unit 2 was of 906 MWe and almost “brand new” in 1979, but its meltdown, the worst accident in U.S. commercial nuclear power plant history, led to heightened concerns among opponents of nuclear energy and the public about safety issues, and has first entered the pantheon of nuclear disaster history to be followed by Chernobyl (1986) and Fukushima (2011) with their tens of billions of dollars in expenses and extensive human and social costs. The Kemmeny Commission, which reported to the President of the US, (Kemmeny, 1979) identified human error and operator “culture” as culprits in the meltdown.

The accident began with failures in the non-nuclear secondary system, followed by a stuck-open pilot-operated relief valve in the primary system that allowed large amounts of nuclear reactor coolant to escape. The mechanical failures were compounded by the initial failure of plant operators to recognize the LOCA due to inadequate training and human factors, including those not involving only reactors, for example, human-computer interaction design oversights relating to ambiguous control room indicators. In particular, a hidden indicator light led an operator to manually override the automatic emergency cooling system of the reactor because he mistakenly believed that there was too much coolant water present in the reactor; he caused the pressure release that released radioactive steam. (US NRC, 2014)

Another problem was the formation of a hydrogen bubble.

> When the reactor's core was uncovered, on the morning of 28 March, a high-temperature chemical reaction between water and the zircalloy metal tubes holding the nuclear fuel pellets had created hydrogen gas. In the afternoon of 28 March, a sudden rise in reactor building pressure shown by the control room instruments indicated a hydrogen burn had occurred. Hydrogen gas also gathered at the top of the reactor vessel. From 30 March through 1 April operators removed this hydrogen gas 'bubble' by periodically opening the vent valve on the reactor cooling system pressurizer. For a time, regulatory (NRC) officials believed the hydrogen bubble could explode, though such an explosion was never possible since there was not enough oxygen in the system. (World Nuclear Association, 2001)

This event, and the deliberate venting of radioactive gases from the plant on Friday morning produced a reading of 1,200 millirems (12 mSv) directly above the stack of the auxiliary building, that created significant anxiety among the public. (World Nuclear Association, 2001) This led to a spontaneous exodus from around the plant, but not an ordered evacuation. While government and industry officials think this situation was only a sign of confusion and not of danger, it indicates that no one was prepared to handle the situation, and if an evacuation had been required, it would have been too late, or at least disorderly and incomplete – witness the 3-day warning before Hurricane Katrina and the loss of 1,836 human lives. The total costs of cleanup were $1 billion over 12 years. The accident was rated a five on the seven-point International Nuclear Event Scale as an "Accident With Wider Consequences." (Ibid.)

Kemmeny Report on TMI (1979)

The measured and thoughtful Report of the President's Commission on the Accident at Three Mile Island (the "Kemmeny" report) focused on the "culture" of operation of nuclear power stations and on operator error without indicting the entire industry. The authors acknowledged,

> We did not examine the entire nuclear industry…We have not dealt with the question of the disposal of radioactive waste or the dangers of the accumulation of waste fuel within nuclear power plants adjacent to the containment buildings. We made no attempt to examine the entire fuel cycle, starting with the mining of uranium. And, of course, we made no examination of the many other sources of radiation, both natural and man-made, that affect all of us. (Kemmeny, 1979)

The authors also did not evaluate the relative risks involved in alternate sources of energy or “reach a conclusion as to whether, as a matter of public policy, the development of commercial nuclear power should be continued or should not be continued.” Yet also acknowledging in 1979 that there were 72 operating reactors in the United States with a capacity of 52,000 megawatts of electric energy and that an additional 92 plants received construction permits and were in various stages of construction, they might indeed have paid attention to these crucial data. (Kemmeny et al., 1979: 3-4) The Kemmeny Report indicated the poor oversight and regulatory operations of the NRC:

> To prevent nuclear accidents as serious as Three Mile Island, fundamental changes will be necessary in the organization, procedures, and practices -- and above all -- in the attitudes of the Nuclear Regulatory Commission and, to the extent that the institutions we investigated are typical, of the nuclear industry. This conclusion speaks of necessary fundamental changes. We do not claim that our proposed recommendations are sufficient to assure the safety of nuclear power. (Ibid.: 7)

The study members recognized the need to improve the quality and operation of equipment toward the end of safety. But they concluded that

> …the basic problems are people-related, we do not mean to limit this term to shortcomings of individual human beings -- although those do exist. We mean more generally that our investigation has revealed problems with the ‘system’ that manufactures, operates, and regulates nuclear power plants. There are structural problems in the various organizations, there are deficiencies in various processes, and there is a lack of communication among key individuals and groups. (Ibid.: 8)

The committee members noted “potentially serious scenarios, such as the break of a huge pipe that carries the water cooling the nuclear reactor,” but concluded that “a preoccupation developed with such large-break accidents as did the attitude that if they could be controlled, we need not worry about the analysis of ‘less important’ accidents.” In part, as a result, “A potentially insignificant incident grew into the TMI accident, with severe damage to the reactor. Since such combinations of minor equipment failures are likely to occur much more often than the huge accidents, they deserve extensive and thorough study. (Ibid.: 9) In reality, operators were poorly prepared for the accident, did not learn from previous ones, did not assimilate warnings from the reactor manufacturer (Babcock and Wilcox), and could not fathom the huge and confusing control panel (during the first minutes over 100 alarms were sounded). The committee, however, shockingly concluded that an accident was bound to occur:

> While the major factor that turned this incident into a serious accident was inappropriate operator action, many factors contributed to the action of the operators, such as deficiencies in their training, lack of clarity in their operating procedures, failure of organizations to learn the proper lessons from previous incidents, and deficiencies in the design of the control room. These shortcomings are attributable to the utility, to suppliers of equipment, and to the federal commission that regulates nuclear power. Therefore – whether or not operator error "explains" this particular case -- given all the above deficiencies, we are convinced that an accident like Three Mile Island was eventually inevitable.” (Ibid., 11)

The Kemmeny Report also recommended greater rights to states to regulate siting and regulation. This would have given them the ability to derail or significantly slow licensing by refusing to permit certain sites from being selected or claiming that stations could not operate because no feasible evacuation plan was possible in case of an accident. But the federal government, the courts, and the NRC have not permitted any turn toward state rights as recommended. This would have created havoc for the industry, for example, by permitting Massachusetts to reject the Seabrook station evacuation plan and delaying its power production.

The Kemmeny Report indicated the poor oversight and regulatory operations of the NRC:

> To prevent nuclear accidents as serious as Three Mile Island, fundamental changes will be necessary in the organization, procedures, and practices -- and above all -- in the attitudes of the Nuclear Regulatory Commission and, to the extent that the institutions we investigated are typical, of the nuclear industry. This conclusion speaks of necessary fundamental changes. We do not claim that our proposed recommendations are sufficient to assure the safety of nuclear power. (Ibid.: 7)

The study members recognized the need to improve the quality and operation of equipment toward the end of safety. But they concluded that "the basic problems are people-related, we do not mean to limit this term to shortcomings of individual human beings -- although those do exist. We mean more generally that our investigation has revealed problems with the 'system' that manufactures, operates, and regulates nuclear power plants. There are structural problems in the various organizations, there are deficiencies in various processes, and there is a lack of communication among key individuals and groups. (Ibid.: 8)

Reforms of NRC after TMI

If reforms of the NRC itself were required, then TMI triggered more debate and considered the precise direction of reforms. Some individuals question whether the agency was slow to respond properly in this and other cases. (See Event 5.) For example, several individuals suggested the appointment of a single, more powerful administrator, rather than the "cumbersome commissioner structure that seemed to interfere with the regulatory behavior of nuclear power." Others worried that a pro-nuclear president would appoint an administrator who might "weaken safety requirements, eliminate intervener rights, and charge ahead with dangerous technologies?" (Ahearne, 1984) According to one review, the functions of the NRC had "little impact on the quality of the NRC's decision making or on the safety of nuclear reactors in general. Moreover, the limited changes that have occurred since Three Mile Island fail[ed] to address several of the larger administrative and political issues concerning the performance of regulatory agencies and how to evaluate it." (Temples, 1982: 355)

Dorothy Nelkin wrote that the NRC responded to the post-TMI criticism with some energy. As a result of the accident and subsequent criticism of the NRC, its staff grew by 14 percent from 2,841 to 3,240 in one year, and its annual budget increased from $325.8 million to $423 million.

Requirements were developed for additional training of reactor operators. Emergency plans include telephone hotlines to a commission emergency response center. The inspection system was improved and the structure of the commission itself reevaluated. But "improved" regulation inevitably increased operating costs and it may also have exacerbated the problems of complexity, compounding the difficulties of management and the risk of systemic effects. (Nelkin, 1981: 138)

Health Effects

According to several studies, the radiation doses of the approximately 2 million people in the affected region were very small and there would be no long term health impacts.

According to the NRC:

> The NRC conducted detailed studies of the accident's radiological consequences, as did the Environmental Protection Agency, the Department of Health, Education and Welfare (now Health and Human Services), the Department of Energy, and the Commonwealth of Pennsylvania. Several independent groups also conducted studies. The approximately 2 million people around TMI-2 during the accident are estimated to have received an average radiation dose of only about 1 millirem above the usual background dose. To put this into context, exposure from a chest X-ray is about 6 millirem and the area's natural radioactive background dose is about 100-125 millirem per year for the area. The accident's maximum dose to a person at the site boundary would have been less than 100 millirem above background.
>
> In the months following the accident, although questions were raised about possible adverse effects from radiation on human, animal, and plant life in the TMI area, none could be directly correlated to the accident. Thousands of environmental samples of air, water, milk, vegetation, soil, and foodstuffs were collected by various government agencies monitoring the area. Very low levels of radionuclides could be attributed to releases from the accident. However, comprehensive investigations and assessments by several well-respected organizations, such as Columbia University and the University of Pittsburgh, have concluded that in spite of serious damage to the reactor, the actual release had negligible effects on the physical health of individuals or the environment. (US NRC, 2014)

3.4. Event 4: Seabrook Nuclear Power Station and Clamshell Alliance Protests

In May 1968 the Public Service Company of New Hampshire (PSNH) announced plans to build a nuclear plant in Newington, NH, on the Great Bay (the site now of multitudinous shopping malls). A year later, in the face of local opposition and higher costs, PSNH gave up this plan. In 1972 the company proposed to build two reactors on the Hampton-Seabrook estuary, of salt marshes and critical habitat for birds and other fauna, along the Atlantic Ocean in Seabrook, NH, the first to come online by 1979, the second in 1981, with a total cost of less than $1 billion. The plans generated extensive public opposition, protest, and occupation of the construction site by the Clamshell Alliance. Protests continued into the 1990s. Construction also drew opposition of the Governor of the Commonwealth of Massachusetts, Mike Dukakis. One reactor was completed at great cost.

Main Actors	PSNH, the State of New Hampshire, the Commonwealth of Massachusetts, the NRC, extensive public protest through Clamshell Alliance, local and state police
When and where did it take place? Change over time?	1968-1990
What type of process was it? How did this change over time?	Protest over the proposed construction of two nuclear power stations in the coastal region of New Hampshire. Protest became large scale. It grew increasingly to reflect concern over the power of local people and their governments against power corporations and the federal government.
Alliances among actors?	The Clamshell Alliance brought together people from a wide range of professions and walks of life in a series of local “clams” or groups. The NRC, the utility and the State of NH worked to head off protest and to see Seabrook Station built. In Massachusetts the Governor’s office (Mike Dukakis) opposed the operation of Seabrook because of fears that no evacuation plan was feasible in case of emergency. In 1978 the Clamshell Alliance split after its Coordinating Committee (CC) agreed to call off a large civil disobedience planned at the power plant site in June, instead of obtaining input and consensus from regional Clam groups. The government of New Hampshire had negotiated the opportunity for the Alliance to hold a pro-solar power and music festival at the Seabrook site to avoid bad publicity and the cost of law enforcement. Twenty thousand people attended. In response to a feeling that a

	massive arrest on the site would overwhelm the state, undermine support and finance for the Seabrook nuclear project, and also result in the costs of hiring police from neighboring states, incarcerating thousands of Clams and paying court expenses offered to let Clamshell hold a solar power fair and concert on the site. This proposal was eventually accepted by Clamshell and a highly successful rally of 20,000 people was held on the site with thousands of Clams also camped out on the Seabrook site. But the political consequences within Clamshell led to a split in the Alliance and the eventual formation of the Coalition for Direct Action that called for continued occupation. (Coalition for Direct Action, 1979)
Transnational concerns?	None
Regulators, trust, procedures?	As for state power and the police, the actions led to mass arrests. In later years, New Hampshire authorities minimized the impact of mass civil disobedience at the Seabrook plant by treating activist trespass as a violation and allowing community service in lieu of fines to limit their effectiveness. Clamshell Alliance members attempted to have their actions taken more seriously by the courts and began staging sit-ins of the office of Republican Governor Judd Gregg. The NRC lost a great deal of trust among New Englanders when it accepted an industry-sponsored emergency evacuation plan for a 10-mile radius. Massachusetts Gov. Michael S. Dukakis refused to file plans for the northeastern Massachusetts towns, contending that geographic and demographic characteristics of the seacoast area make it impossible to evacuate safely under any conditions.
Public-nuclear interactions?	The Clamshell Alliance was formed in Rye, NH, at a backyard picnic table in July 1976 by New England activists who nuclear power, leading to a prolonged battle between it, the NRC, the PSNH, one of the smallest utilities in the nation, NH, and MA.
Video	“Seabrook 1977.” (Leppzer, 1977). See excerpt at https://www.youtube.com/watch?v=N3rS8hzW2pA

The NRC granted PSNH a construction permit in 1982 for Seabrook, but unit 2 was never built, scrapped when 25 percent complete, and its major components sold to other plants. The cost of one reactor alone ballooned to $4.3 billion by the time it was completed in 1986 (eight times the initial estimate of $1 billion for both units). When the sole reactor came online commercially in August 1990, Seabrook had cost $6.2 billion, and led to the bankruptcy of PSNH. The plant was then sold to several separate utilities who, in 2002, sold their shares to NextEra Energy Resources which owns 88% of the station, with the remainder owned by municipal utilities of Massachusetts. The grotesquely expensive station – and the decision to site it near heavily populated areas (Portsmouth, NH; Boston, MA) with inadequate evacuation plans and concerns about safety generated a massive public response in the Clamshell Alliance Protests. (See Bedford, 1990; Bove, 1978; Coalition for Direct Action, 1979)

The Seabrook experience revealed again that utilities, perhaps inadvertently, but always significantly, underestimated the costs of nuclear power. In the case of Seabrook it was able easily to pass along many of those costs, for example in rate hikes for consumers, even before the reactors generated power. PSNH was permitted several rate hikes, one of 17% or $27 million. A RAND study estimated that construction costs of nuclear power plants would double in real dollars every six years or less because of recurrent design failures and the need to build in redundancies and other safety systems. This was surely the case with Seabrook. (Mooz, 1979; Bove, 1978: 37) The growing costs of Seabrook, and real concerns that rapid and safe evacuation from the densely populated seacoast region of New Hampshire and northern Massachusetts was nearly impossible, led to mass protests against the station and to the formation of the Clamshell Alliance to stop the project. Stever found that lack of openness in the licensing process contributed significantly to cost overruns and ensured heightened conflict over siting. (Stever, 1980)

In 1974, at Wyhl, West Germany, 28,000 people occupied the site of a proposed nuclear station to stop its construction in a nature preserve. People remained on site until the project was abandoned. (See Federal Republic of Germany Country Report) Seeking similar results, The Clamshell Alliance, an umbrella organization of 15 anti-nuclear groups, was formed at a July 1976 meeting of 50 people, almost all of whom were NH residents. The goal of the Alliance was to halt Seabrook construction and to force cancelation of the project by any means necessary within the context of "non-violent, direct action." (Coalition for Direct Action, 1979)

As soon as the NRC issued a construction license in summer 1976, 200 New England residents rallied at the edge of the future power plant site, on the seacoast saltmarsh as the Clamshell Alliance, 18 of whom were arrested for "criminal trespass" and sentenced to time in jail. A week later, 188 other New England citizens returned to the Seabrook site; they too were arrested. As one of the founders wrote, "By the early spring of April 1977, two thousand 'Clams,' as they came to be known, had returned to the site to non-violently reclaim the land and declare the ocean front 'nuclear free." Over the years dozens of Clams were arrested for nonviolent civil disobedience at Seabrook in the effort to stop nuclear power, including two state legislators, one from Massachusetts and one from New Hampshire. (US NRC, 1979; Gunter, 1990)

Hundreds of demonstrators descended on the plant when PSNH began the first power tests in June 1985, with 627 arrested for trespassing. The protesters included children and handicapped people. The protestors chanted, "Shame on us" and carried signs that read "In Mourning for the Late, Great State of New Hampshire" and "Remember Chernobyl." Ron Sher, a Seabrook spokesman, dismissed the protestors as failing to recognize "that nuclear energy is a viable energy option." The tests would permit moving through a series of licenses to full power, and to overcome years of delays and cost overruns. (Gold, 1989)

The New England Coalition on Nuclear Pollution had one short-lived victory against Seabrook. They secured an initial favorable ruling by a board of the NRC to postpone Seabrook's construction until waste issues were resolved. But five days later, the order was rescinded and waste issues remained unresolved. (Seabrook Clamshell Alliance, 1976: 15)

The Clamshell allows sought non-violent occupation and "restoration of the construction site by setting up projects demonstrating the potential of alternative, renewable energy sources (e.g., solar and wind energy) in agriculture, aquaculture, and silvaculture (tree products)." All participants had to be trained in non-violent action, "no weapons, no property damage or destruction, no running at any time, no breaking through police lines, no dogs, no drugs or alcohol. In case of confrontation, we will sit down. (Ibid.: 15)

As a leading Cclam, Paul Gunter, recalled, as part of the federal licensing process, the Nuclear Regulatory Commission had required individual state government approval of a nuclear plants' emergency evacuation plans.

> After the Chernobyl nuclear accident, public worries about nuclear plant safety mounted. As a result, Governor Michael Dukakis of Massachusetts withdrew his state's approval of the Seabrook Emergency Response Plan. He cited his grave doubts about the feasibility of effective state evacuation and sheltering capacities in the event of a nuclear accident. Then

> the Nuclear Regulatory Commission reversed its earlier ruling that required state and local approval of emergency response plans. In an effort to keep the Seabrook licensing process alive, the Federal Government decided unilaterally to overrule the concerns of the State of Massachusetts.

Gunter noted, the NRC then recognized a bankrupt company, PSNH, to be competent enough to develop an evacuation plan. (Gunter, 1990)

In November 1987 the Nuclear Regulatory Commission removed a major stumbling block to licensing the Seabrook NPP for low-power testing when its commission voted 4-1 “that a new utility-drafted evacuation plan for the six Massachusetts towns that fall within Seabrook's 10-mile emergency zone could be considered in lieu of a state proposal.” Massachusetts Gov. Michael S. Dukakis refused to file plans for the northeastern Massachusetts towns, contending that geographic and demographic characteristics of the seacoast area make it impossible to evacuate safely under any conditions. That stance has further stalled the oft-delayed $5.1 billion plant. (Journal of Commerce, 1987)

In 2009, NextEra Energy Seabrook noted the intrusion of moisture into sections of walls in certain below-grade structures at the Seabrook nuclear power plant that might cause the degradation of some of the concrete as evidenced by pattern cracking. The NRC put the station under special oversight for 3 years until the problem was resolved. (US NRC, 2016c)

3.5. Event 5: Davis-Besse NPP Operation and Reactor Head Corrosion (2002)

The Davis–Besse Nuclear Power Station near Oak Harbor, Ohio, has a single PWR. On March 5, 2002, maintenance workers discovered that corrosion had eaten a football-sized hole into the reactor vessel head that might have led to a meltdown. The NRC shut down the station for two years to perform the necessary repairs and maintenance for safe operation. It imposed its largest fine ever—more than $5,540,000—against FirstEnergy for the actions that led to the corrosion. (US NRC, 2005) The company paid an additional $28 million in fines under a settlement with the U.S. Department of Justice. The history of Davis-Besse reveals that a power station may be operated, according to regulators, even in the face of persistent, troubling repair, maintenance and other problems.

Main Actors	Original owners: Cleveland Electrical Illuminating and Toledo Edison, then by the FirstEnergy Nuclear Operating Company subsidiary of FirstEnergy Corp, NRC, General Accounting Office (GAO), OhioPIRG, Harvey Wasserman
When and where did it take place? Change over time?	2002 – at the Davis-Besse NPP, one of the most poorly operating stations in the US
What type of process was it? How did this change overtime?	A serious maintenance and repair problem that could have resulted in a major nuclear accident – a meltdown. The NRC required the shutdown of the station for two years until 2004, and with the Justice Department fined Davis-Besse $33,540,000. Problems with the reactor continued to 2016. Industry and the regulator have been aware of these ongoing problems for decades.
Alliances among actors?	Since the late 1990s the NRC – the regulator—has actively engaged its supervisory functions that lead at times to tensions with industry. At the same time the GAO suggests still greater improvements in these functions. The public consists of a loose group of individuals.
Transnational concerns?	General reactor safety.
Regulators, trust, procedures?	Many people in Ohio worry greatly about the safety of the station given the stream of problems that have hampered its operation and the difficulties the regulators have encountered in improving performance – with very little margin for reactor safety. Industry and the regulator have been aware of these ongoing problems for decades.
Public-nuclear interactions?	Demonstrations against the station began in 1979 after Toledo Edison shut down the station to determine if, in the light of TMI, any changes in operating safety needed to be made. Another demonstration involved 200 people in December 1981. In August 2002, more than a hundred area residents and activists from Ohio, Indiana, and Michigan came to Crane Creek State Park to protest repair efforts at the Davis-Besse nuclear plant. In 2004 over 400 activists who sent letters asking state officials to oppose restarting Davis-Besse. In June 2011 over 250 anti-nuclear activists protested the continued operation of the Davis-Besse nuclear power plant. In January 2012 About 20 people participated in a skit in front Davis-Besse Nuclear Power Station before they attended a public meeting about shield building cracks at the plant. “We have nuclear-grade duct tape, nuclear-grade Gorilla Glue and nuclear-grade spackling,” said Kevin Kamps, dressed as C. Montgomery Burns, the owner of the Springfield Nuclear Power Plant in “The Simpsons.”

Video	Myla Reson, (2015). “Davis Besse: Ohio's Costly Nuclear Nightmare,” https://www.youtube.com/watch?v=yefKEDF0uuM

The Davis-Besse NPP has, in comparison with other NPPs, a very poor operating record. (Wasserman, 2015). In 1977 a stuck relief valve was a “precursor accident” to the 1979 Three Mile Island meltdown. In 1985 a LOCA, the worst since Three Mile Island, closed Davis-Besse for a year. In 1998 a tornado caused a total loss of power, destroying the plant's warning, communication and emergency systems, threatening a meltdown. And in 2002, the operator neglected maintenance and upkeep to the extent that leaking borated water was able to eat a 7” hole in the reactor's pressure vessel lid, leaving only a 3/16" liner to contain the coolant and prevent a meltdown. (US NRC, 2008) The plant closed for two years costing ratepayers $600 million and resulting in a $33.5 million fine, the largest in NRC history. In 2010, the utility discovered it had to replace the vessel head again.

The reactor pressure vessel (RPV) heads of PWRs have penetrations for control rod drive mechanisms (CRDMs) and instrumentation systems made from nickel-based alloys and related weld metals. Primary coolant and the operating conditions of PWR plants can cause cracking of these nickel-based alloys and weldments through a process called primary water stress corrosion cracking (PWSCC). In response to the detection of PWSCC at several plants, the NRC issued NRC Bulletin 2001-01, “Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles,” which requested information related to licensees’ programs for inspection of vessel head penetration (VHP) nozzles. (US NRC, 2001) Yet Davis-Besse failed to respond. According to a subsequent report,

> On February 16, 2002, in response to Bulletin 2001-01, the Davis-Besse Nuclear Power Station (DBNPS), located in Oak Harbor, Ohio, began a refueling outage with the intent to perform work that included remotely inspecting the VHP nozzles from underneath the head focusing on the CRDMs. The licensee found that three CRDM nozzles had indications of through-wall axial cracking. Specifically, the licensee found these indications in CRDM nozzles 1, 2, and 3, which are located near the top of the RPV head. (US NRC, 2008: 2)

NRC officials fined Davis-Besse for a variety of reasons. One was the fact that during the early 1990s, the NRC and industry recognized the potential for boric acid corrosion of an RPV head, and urged attention to it. An NRC task force concluded that the DBNPS VHP nozzle leakage and RPV head degradation event was preventable. At the station, such early indications of RPV corrosion were missed as radiation element system filters being clogged by boric acid and corrosion fins, the build up of boric acid deposits on containment air cooler fins and large amounts of boric acid deposits on the RPV head.(US NRC, 2008: 5-6) A task force concluded that the event was not prevented because the NRC, DBNPS, and the nuclear industry failed to adequately review, assess, and follow-up on relevant operating experience, DBNPS failed to assure that plant safety issues received appropriate attention, and the NRC failed to integrate known or available information into its assessments of DBNPS's safety performance.(Ibid.: 6-8)

As in other cases, the NRC blamed "safety culture weaknesses" as one of the root causes of the Davis Besse accident. Officials claimed to take "significant steps within the Reactor Oversight Process to strengthen the ability to detect a weak safety culture in our inspections and performance assessments. In this context, safety culture is defined as 'that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance.'"(Ibid.: 11) The constant reference to weak safety culture in the industry reveals that this culture is far spread and extensive, not an anomalous situation, as the case of Three Mile Island indicated.

The GAO was critical of the NRC in the early 2000s for its monitoring and supervisory roles, although noted improvement. According to the GAO in 2006, the NRC improved its safety oversight functions. Between 2001 and 2006 it produced over 4,000 inspection findings for failure fully to comply with safe operating procedures, and the NRC subjected 79 of the 103 plants – 80%!! – to increased oversight for some time, and 5 plants to the highest level of oversight – due to the "more systematic nature of performance problems." (US GAO, 2006a: i)

If 80% of NPPs required increased oversight in that five-year period, then perhaps safety remains a significant issue even when the NRC has improved its oversight functions. Indeed, the GAO report notes, the NRC "has been slow to act on needed improvements, particularly in improving the agency's ability to identify and address early indications of declining safety performance." Many stakeholders believe that changes “could enable NRC to better identify safety culture issues and thus provide earlier indications of declining plant safety performance.” Industry has pushed back because it believes that the changes could “introduce undue subjectivity to NRC’s oversight, given the difficulty in measure these often intangible and complex concepts.” The GAO notes, the NRC “was reluctant to incorporate safety culture into the [Reactor Oversight Process] because it considered this type of activity as a management function, and NRC did not believe that it should be directly involved in managing licensees’ plants.” (Ibid.)

The GAO had noted NRC oversight problems already in 1998-99 in its “inconsistent treatment owing to lack of specific criteria, subjective nature of the process, ineffective process to ensure that licensees maintain competent management.” Prior to 2000, the NRC’s oversight of plants’ compliance was criticized because it did not always focus on the most importance safety issues and some activities were redundant, inefficient, and overly subjective. (Ibid.: 1) The fiasco at Davis-Besse, the 9/11 terrorist attacks, loss of qualified inspectors, and other problems exacerbated these difficulties. In 2004 NRC increased inspection by 9% and in 2005 another 5%. (Ibid.: 10)

How safe is the station today? To replace aging, deteriorating, damaged parts, the operator has made four unprecedented large cuts through the Davis-Besse concrete shield building that prevents release of lethal radiation. In 2011 a series of cracks and concrete voids were discovered, the cause of which is unknown. NRC engineers have calculated a minor earthquake or accident could cause the shield building to collapse onto the reactor releasing catastrophic radiation.

4. Facts and Figures

4.1. Data summary

The US has 99 currently operating commercial nuclear reactors, or 22% of the total 446 in the world. There are over sixty reactors currently under construction in the world, 20 in China, and 5 in the United States, although a number of utilities have entered the process to build new NPPs.

- Nuclear power took off in the United States in the 1960s and 1970s, reaching a peak in construction permits being issued and units brought on line in the 1970s and 1980s. Most of the NPPs are located in the eastern and southern US, and most of the requests for new permits are in southern states.
- Twenty-eight (28) units in the US have been permanently closed, many in the 1970s – first generation smaller units, and again in the 1990s. The general trend has been to work with the federal government, the NRC, and state governments to secure licenses to extend up to 20 years the life of existing stations.
- The US is a nation of electricity based on coal and increasingly natural gas. But nuclear power provides 20% of electricity and has provided roughly this percentage for many years.
- Most NPPs are located near major urban centers to keep electricity transmission costs down, in the eastern and southern states, and on the west coast.

4.2. Key dates and abbreviations

Key dates:

1941	Letter from Einstein and Szilard to Roosevelt on need for atomic bomb
1942	Manhattan Project commences
1945	July 1st, Alamagordo, bomb test
	August, bombing of Hiroshima and Nagasaki
1946	Atomic Energy Act of 1946, Formation of AEC
1953	Eisenhower Speech, UN, “Atoms for Peace”
1954	Atomic Energy Act of 1954
	Obninsk (south of Moscow) Reactor goes critical at 5,000 kW

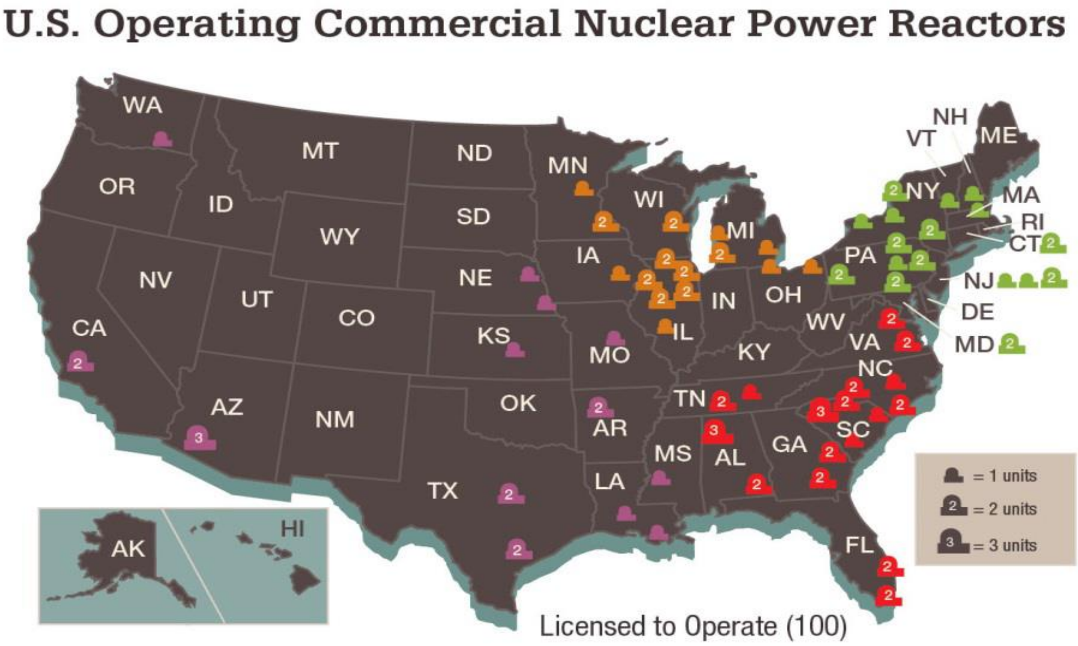
1958	Shippingport, PA, Nuclear Power Station goes critical at 60,000 kW
1962	*Civilian Nuclear Power: A Report to the President*
1966	Meltdown of Detroit's LMFBR "Enrico Fermi"
1969	Sheldon Novick publishes *The Careless Atom*
1975	WASH-1400 – the "Rassmussen Report"
1973	AEC → NRC and creation of ERDA – Later DOE
1979	Three Mile Island Disaster
1979	The Kemmeny Report
1987	The Nuclear Waste Policy Act of 1987

Abbreviations:

ACRS	AEC Advisory Committee on Reactor Safety
AEC	Atomic Energy Committee
BWR	Boiling Water Reactor
ConEd	Consolidated Edison (Electric) Co.
DOE	Department of Energy
ERB-1	Experimental Breeder Reactor-1
ECCS	Emergency Core Cooling System
EIA	Energy Information Administration (US)
ERDA	Energy Research and Development Administration
GAO	General Accounting Office
JCAE	Joint Committee on Atomic Energy
LMFBR	Liquid Metal Fast Breeder Reactor
LOCA	Loss of Coolant Accident
MW	Megawatt
NGOs	Non-governmental organization
NPP	Nuclear power plant
NRC	Nuclear Regulatory Commission
NRDC	National Resources Defense Council
ORNL	Oak Ridge National Laboratory
PG&E	Pacific Gas and Electric

PDRC	Power Demonstration Reactor Corporation
PSNH	Public Service of New Hampshire
PWR	Pressurized Water Reactor
SNF	Spent nuclear fuel
TMI	Three Mile Island
TVA	Tennessee Valley Authority
UCS	Union of Concerned Scientists
WPPSS	Washington Public Power Supply System

4.3. Map of nuclear power plants



Source: Nuclear Regulatory Commission

4.4. List of reactors and technical, chronological details

US Commercial Nuclear Power Stations, 1955-2011

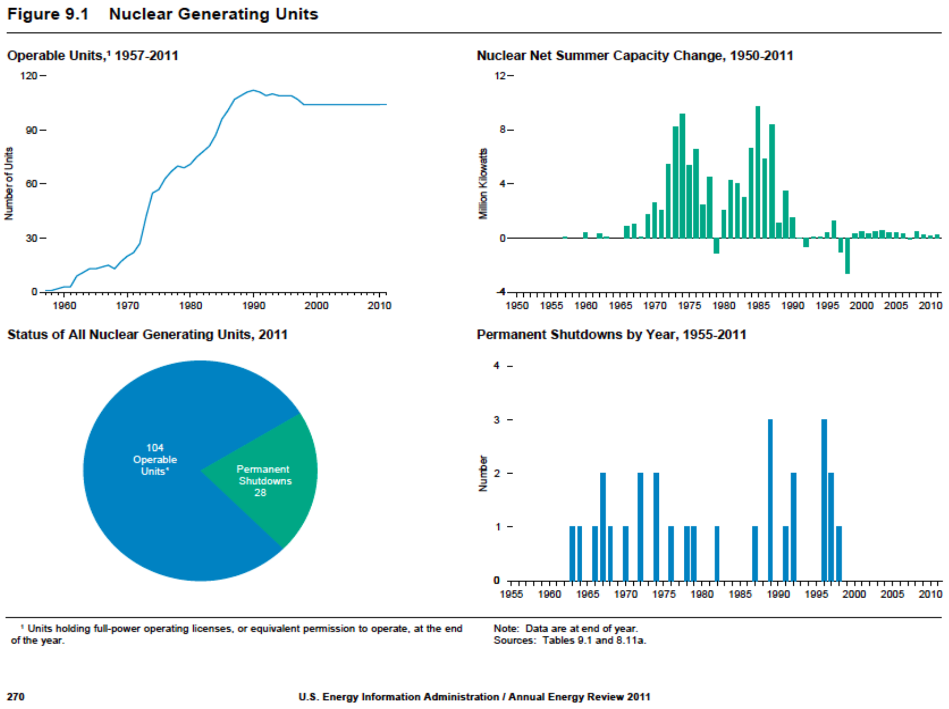


Figure 9.1 Nuclear Generating Units

Operable Units,[1] 1957-2011

Nuclear Net Summer Capacity Change, 1950-2011

Status of All Nuclear Generating Units, 2011

Permanent Shutdowns by Year, 1955-2011

[1] Units holding full-power operating licenses, or equivalent permission to operate, at the end of the year.

Note: Data are at end of year.
Sources: Tables 9.1 and 8.11a.

270 U.S. Energy Information Administration / Annual Energy Review 2011

Source: US Energy Information Administration

US Nuclear Reactors, by Construction Permits Issued and Operable Units, 1955-2011

Years	Construction Permits	Operable Units	Units Added in 5 year period
1955-60	15	3	3
1961-65	13	13	10
1966-70	59	20	7
1970-75	58	57	37
1976-80*	39	71	14
1981-85	0	96	25
1986-90**	0	112	16
1991-95	0	109	1 (-shutdowns)
1996-00	0	104	1 (-shutdowns)
2001-11	0	99	

** TMI in 1979. ** Chernobyl in 1986.*

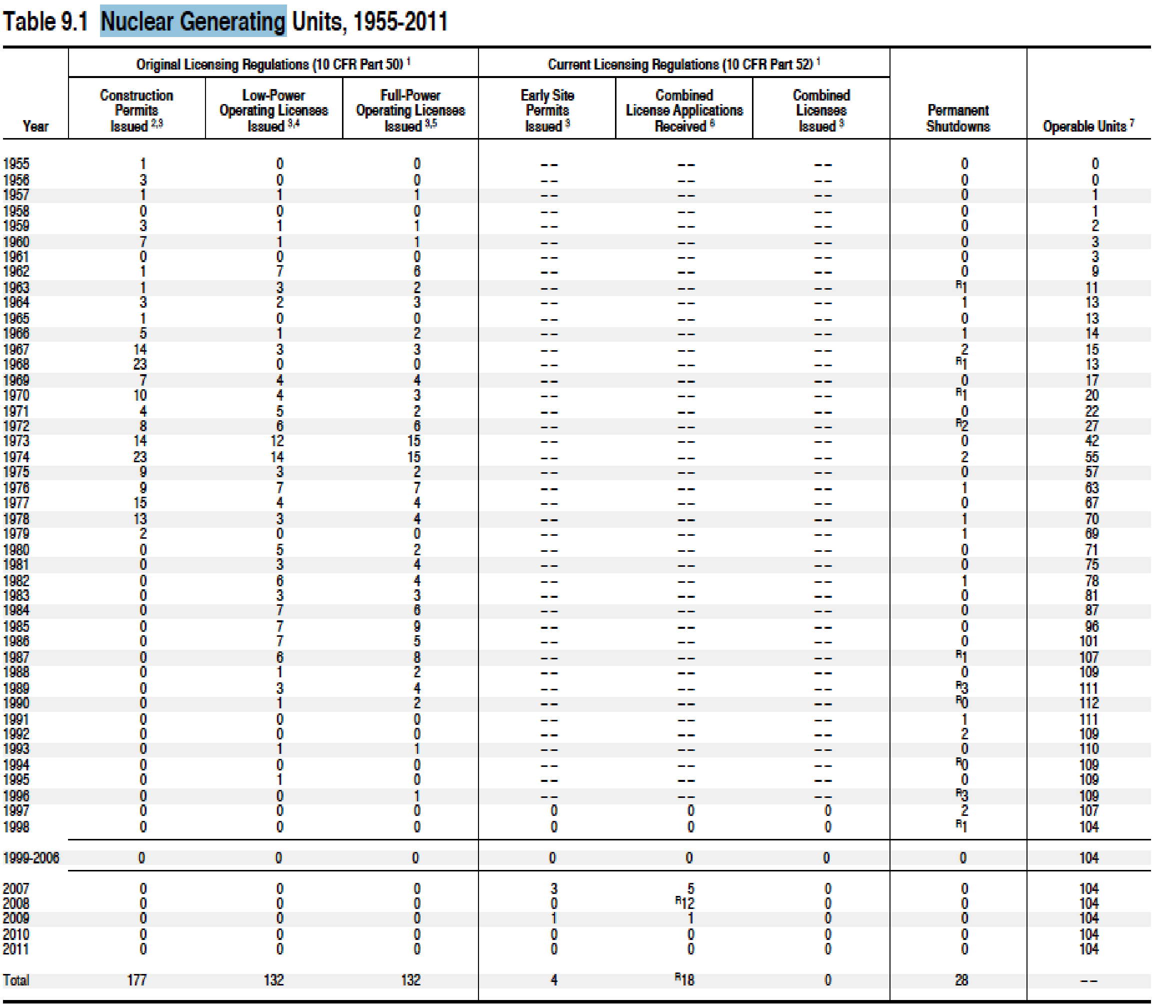
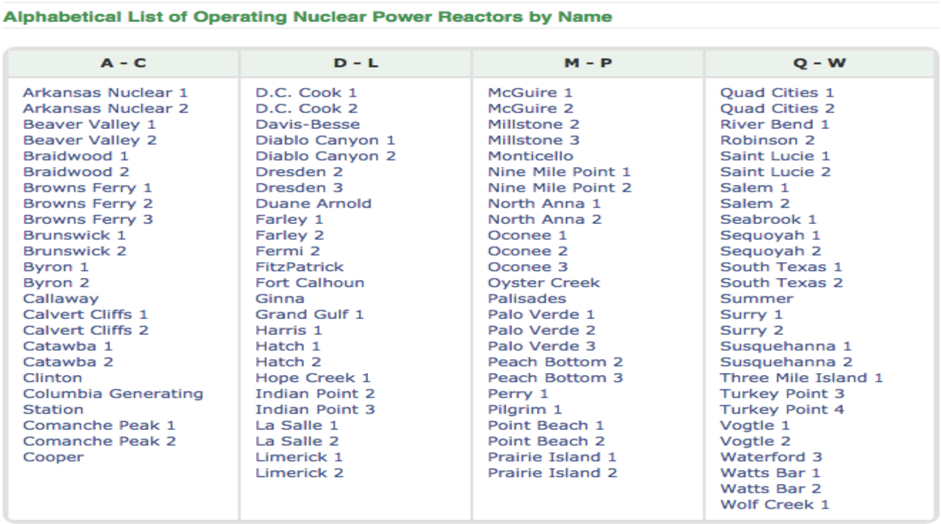


Table 9.1 Nuclear Generating Units, 1955-2011

Year	Original Licensing Regulations (10 CFR Part 50) [1]			Current Licensing Regulations (10 CFR Part 52) [1]			Permanent Shutdowns	Operable Units [7]
	Construction Permits Issued [2,3]	Low-Power Operating Licenses Issued [3,4]	Full-Power Operating Licenses Issued [3,5]	Early Site Permits Issued [3]	Combined License Applications Received [6]	Combined Licenses Issued [3]		
1955	1	0	0	--	--	--	0	0
1956	3	0	0	--	--	--	0	0
1957	1	1	1	--	--	--	0	1
1958	0	0	0	--	--	--	0	1
1959	3	1	1	--	--	--	0	2
1960	7	1	1	--	--	--	0	3
1961	0	0	0	--	--	--	0	3
1962	1	7	6	--	--	--	0	9
1963	1	3	2	--	--	--	^{R}1	11
1964	3	2	3	--	--	--	1	13
1965	1	0	0	--	--	--	0	13
1966	5	1	2	--	--	--	1	14
1967	14	3	3	--	--	--	2	15
1968	23	0	0	--	--	--	^{R}1	13
1969	7	4	4	--	--	--	0	17
1970	10	4	3	--	--	--	^{R}1	20
1971	4	5	2	--	--	--	0	22
1972	8	6	6	--	--	--	^{R}2	27
1973	14	12	15	--	--	--	0	42
1974	23	14	15	--	--	--	2	55
1975	9	3	2	--	--	--	0	57
1976	9	7	7	--	--	--	1	63
1977	15	4	4	--	--	--	0	67
1978	13	3	4	--	--	--	1	70
1979	2	0	0	--	--	--	1	69
1980	0	5	2	--	--	--	0	71
1981	0	3	4	--	--	--	0	75
1982	0	6	4	--	--	--	1	78
1983	0	3	3	--	--	--	0	81
1984	0	7	6	--	--	--	0	87
1985	0	7	9	--	--	--	0	96
1986	0	7	5	--	--	--	0	101
1987	0	6	8	--	--	--	^{R}1	107
1988	0	1	2	--	--	--	0	109
1989	0	3	4	--	--	--	^{R}3	111
1990	0	1	2	--	--	--	^{R}0	112
1991	0	0	0	--	--	--	1	111
1992	0	0	0	--	--	--	2	109
1993	0	1	1	--	--	--	0	110
1994	0	0	0	--	--	--	^{R}0	109
1995	0	1	0	--	--	--	0	109
1996	0	0	1	--	--	--	^{R}3	109
1997	0	0	0	0	0	0	2	107
1998	0	0	0	0	0	0	^{R}1	104
1999-2006	0	0	0	0	0	0	0	104
2007	0	0	0	3	5	0	0	104
2008	0	0	0	0	^{R}12	0	0	104
2009	0	0	0	1	1	0	0	104
2010	0	0	0	0	0	0	0	104
2011	0	0	0	0	0	0	0	104
Total	177	132	132	4	^{R}18	0	28	--

Source: US EIA, 2011.



Alphabetical List of Operating Nuclear Power Reactors by Name

A - C

- Arkansas Nuclear 1
- Arkansas Nuclear 2
- Beaver Valley 1
- Beaver Valley 2
- Braidwood 1
- Braidwood 2
- Browns Ferry 1
- Browns Ferry 2
- Browns Ferry 3
- Brunswick 1
- Brunswick 2
- Byron 1
- Byron 2
- Callaway
- Calvert Cliffs 1
- Calvert Cliffs 2
- Catawba 1
- Catawba 2
- Clinton
- Columbia Generating Station
- Comanche Peak 1
- Comanche Peak 2
- Cooper

D - L

- D.C. Cook 1
- D.C. Cook 2
- Davis-Besse
- Diablo Canyon 1
- Diablo Canyon 2
- Dresden 2
- Dresden 3
- Duane Arnold
- Farley 1
- Farley 2
- Fermi 2
- FitzPatrick
- Fort Calhoun
- Ginna
- Grand Gulf 1
- Harris 1
- Hatch 1
- Hatch 2
- Hope Creek 1
- Indian Point 2
- Indian Point 3
- La Salle 1
- La Salle 2
- Limerick 1
- Limerick 2

M - P

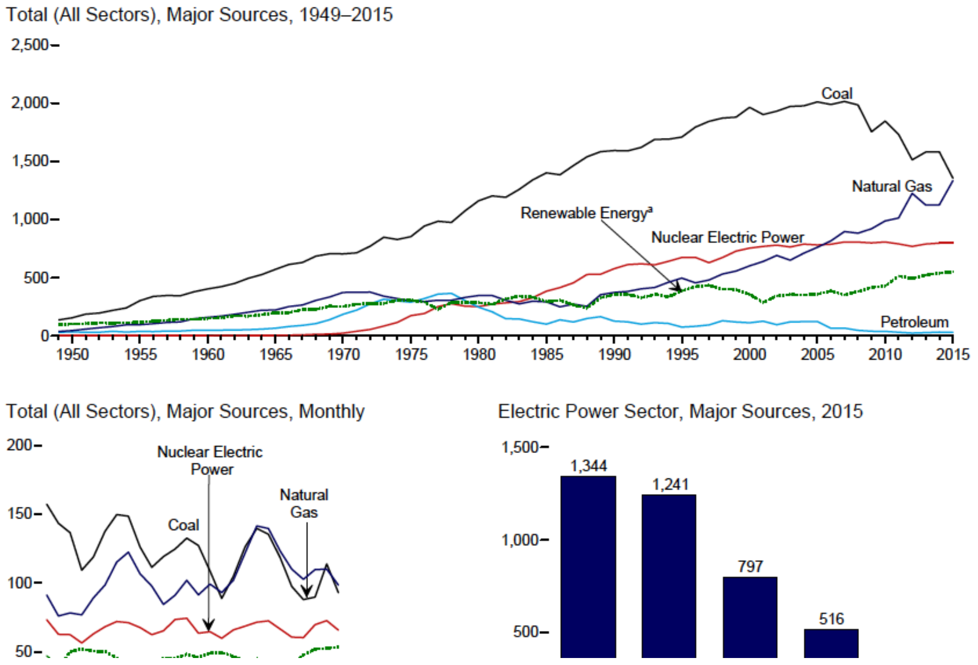
- McGuire 1
- McGuire 2
- Millstone 2
- Millstone 3
- Monticello
- Nine Mile Point 1
- Nine Mile Point 2
- North Anna 1
- North Anna 2
- Oconee 1
- Oconee 2
- Oconee 3
- Oyster Creek
- Palisades
- Palo Verde 1
- Palo Verde 2
- Palo Verde 3
- Peach Bottom 2
- Peach Bottom 3
- Perry 1
- Pilgrim 1
- Point Beach 1
- Point Beach 2
- Prairie Island 1
- Prairie Island 2

Q - W

- Quad Cities 1
- Quad Cities 2
- River Bend 1
- Robinson 2
- Saint Lucie 1
- Saint Lucie 2
- Salem 1
- Salem 2
- Seabrook 1
- Sequoyah 1
- Sequoyah 2
- South Texas 1
- South Texas 2
- Summer
- Surry 1
- Surry 2
- Susquehanna 1
- Susquehanna 2
- Three Mile Island 1
- Turkey Point 3
- Turkey Point 4
- Vogtle 1
- Vogtle 2
- Waterford 3
- Watts Bar 1
- Watts Bar 2
- Wolf Creek 1

Source: NRC

Figure 7.2 Electricity Net Generation
(Billion Kilowatthours)

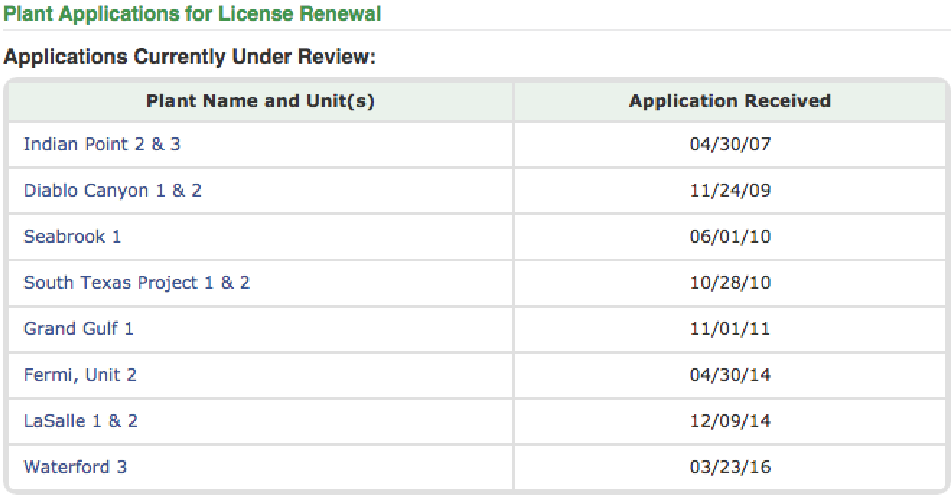


Total (All Sectors), Major Sources, 1949–2015

Total (All Sectors), Major Sources, Monthly

Electric Power Sector, Major Sources, 2015

Source: US EIA



Plant Applications for License Renewal

Applications Currently Under Review:

Plant Name and Unit(s)	Application Received
Indian Point 2 & 3	04/30/07
Diablo Canyon 1 & 2	11/24/09
Seabrook 1	06/01/10
South Texas Project 1 & 2	10/28/10
Grand Gulf 1	11/01/11
Fermi, Unit 2	04/30/14
LaSalle 1 & 2	12/09/14
Waterford 3	03/23/16

Source: NRC

4.5. List of influencing actors

Major National Groups Influencing Public Opinion,

For and Against Nuclear Power (OTA, 1984: 215)

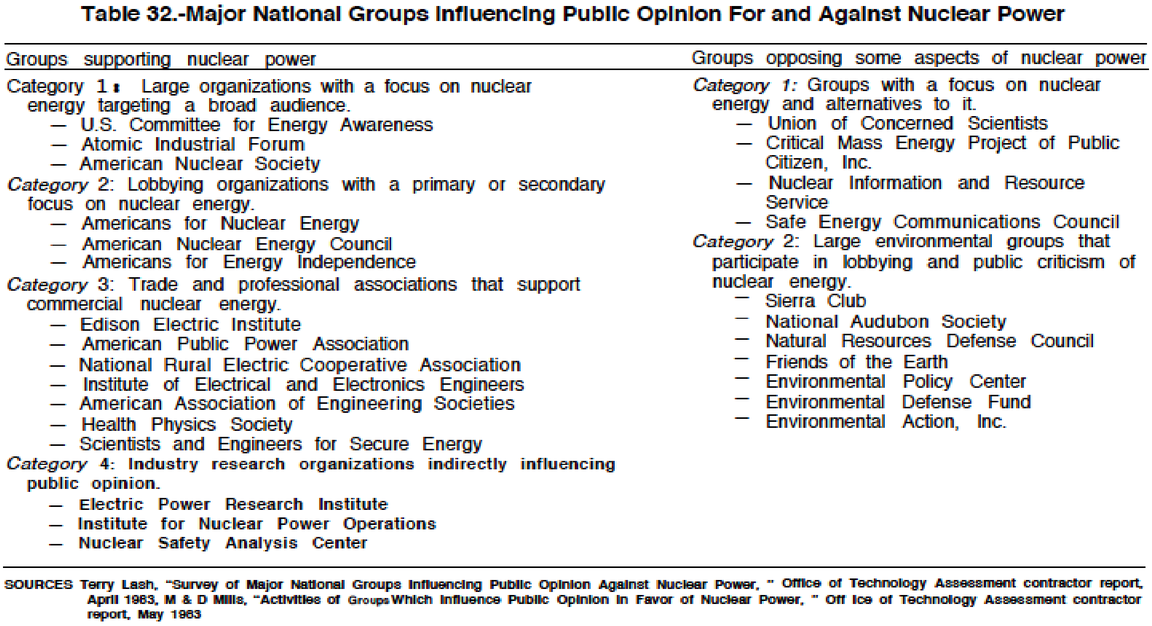


Table 32.-Major National Groups Influencing Public Opinion For and Against Nuclear Power

Groups supporting nuclear power	Groups opposing some aspects of nuclear power
Category 1: Large organizations with a focus on nuclear energy targeting a broad audience. — U.S. Committee for Energy Awareness — Atomic Industrial Forum — American Nuclear Society	*Category 1:* Groups with a focus on nuclear energy and alternatives to it. — Union of Concerned Scientists — Critical Mass Energy Project of Public Citizen, Inc. — Nuclear Information and Resource Service — Safe Energy Communications Council
Category 2: Lobbying organizations with a primary or secondary focus on nuclear energy. — Americans for Nuclear Energy — American Nuclear Energy Council — Americans for Energy Independence	*Category* 2: Large environmental groups that participate in lobbying and public criticism of nuclear energy. — Sierra Club — National Audubon Society — Natural Resources Defense Council — Friends of the Earth — Environmental Policy Center — Environmental Defense Fund — Environmental Action, Inc.
Category 3: Trade and professional associations that support commercial nuclear energy. — Edison Electric Institute — American Public Power Association — National Rural Electric Cooperative Association — Institute of Electrical and Electronics Engineers — American Association of Engineering Societies — Health Physics Society — Scientists and Engineers for Secure Energy	
Category 4: Industry research organizations indirectly influencing public opinion. — Electric Power Research Institute — Institute for Nuclear Power Operations — Nuclear Safety Analysis Center	

SOURCES Terry Lash, "Survey of Major National Groups Influencing Public Opinion Against Nuclear Power, " Office of Technology Assessment contractor report, April 1963, M & D Mills, "Activities of Groups Which Influence Public Opinion In Favor of Nuclear Power, " Off Ice of Technology Assessment contractor report, May 1963

5. References

ACRS (1970?) (Advisory Committee on Reactor Safety of NRC), as cited in UCS (?), "Fermi Unit 1," at http://www.ucsusa.org/sites/default/files/legacy/assets/documents/nuclear_power/fermi-1.pdf.

John F. Ahearne, Alvin M. Weinberg and Irving Spiewak. 1984. "Administration of the NRC," *Science, New Series*, Vol. 225, No. 4663 (Aug. 17, 1984), p. 672.

Lamar Alexander, Sheldon Whitehouse. 2016. "To Slow Global Warming, We Need Nuclear Power," December 21, 2016, *New York Times*, at http://www.nytimes.com/2016/12/21/opinion/to-slow-global-warming-we-need-nuclear-power.html?_r=0

ASME, n. d., "Shippingport Nuclear Power Station. 1958," at https://www.asme.org/about-asme/who-we-are/engineering-history/landmarks/47-shippingport-nuclear-power-station as accessed June 2, 2016.

AEC (Atomic Energy Commission). 1957. *Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants* (Washington: AEC, 1957).

AEC. 1958?. "Power and Promise [Film]," at https://archive.org/details/28792AtomicPowerAndPromise

AEC. 1973. *The Safety of Nuclear Power Reactors ((light water-cooled) and Related Facilities*, WASH-1250 (Washington: AEC, July 1973).

Brian Balogh. 1991. *Chain Reaction: Expert Debate and Public Participation in American Commercial Nuclear Power, 1945-1975* (New York: Cambridge University Press, 1991).

Will J. Bangs. 1961. "The Price-Anderson Act: A Half Billion Dollars of Federal Indemnity," *American Bar Association Journal*, Vol. 47, No. 12 (December, 1961), pp. 1178-1181.

Rochelle Becker. 2011. "A brief history of California's nuclear reactor oversight: a regulatory timeline with recommendations for the present," April 14, 2011, Alliance for Nuclear Responsibility, PO Box 1328 San Luis Obispo, CA 93406.

Henry Bedford. 1990 *Seabrook Station. Citizen Politics and Nuclear Power*. (Amherst: University of Massachusetts Press, 1990.)

Frank Bove. 1978. "Clamshell Will Return in Force," *Science for the People*, vol. 10, no. 3 (May/June 1978), p. 37.

Paul Boyer. 1985. *By the Bomb's Early Light* (Chapel Hill: University of North Carolina Press, 1985).

Coalition for Direct Action (?). 1977(?). "Seabrook Station Conflict." Uploaded February 26, 2011, at https://www.youtube.com/watch?v=USgcd5XZEoM as accessed December 25, 2016.

Coalition for Direct Action. 1979. *Let's Shut Down Seabrook!* (Cambridge: Boston Clamshell, 1979).

CLP Group. 2013. “Pressurised Water Reactor Vs Boiling Water Reactor,” at https://www.clpgroup.com/NuclearEnergy/Eng/power/power4_1_2.aspx as accessed June 2, 2016.

Thomas Cochran et al.. 2005. *Position Paper: Commercial Nuclear Power* (Washington: NRDC, October 2005).

David Dinsmore Comey. 1976. *Not Man Apart* (Friends of the Earth, California, 1976) at http://www.ccnr.org/browns_ferry.html as accessed December 25, 2016.

Erik Conway, Naomi Oreskes. *Merchants of Doubt* (New York: Bloomsbury, 2004)

Direct Action, *Direct Action 1981 Handbook*

Hazel Gaudet Erskine. 1963. "The Polls: Atomic Weapons and Nuclear Energy," *Public Opinion Quarterly*, XXVII (1963), p. 164

Rodney Ewing and Allison Macfarlane. 2002. “Yucca Mountain,” *Science*, vol. 296 (April 22, 2002), pp 659-670.

Daniel Ford. 1982. *The Cult of the Atom* (New York: Simon and Schuster, 1982).

John Fuller. 1975. *We Almost Lost Detroit* (New York: Reader’s Digest Press, 1975).

William A. Gamson, Andre Modigliani. 1989. “Media Discourse and Public Opinion on Nuclear Power: A Constructionist Approach,” *American Journal of Sociology*, Vol. 95, No. 1 (Jul., 1989), pp. 1-37.

Allan Gold. 1989. “Hundreds Arrested Over Seabrook Test,” *The New York Times*, June 5, 1989.

Henry J. Gomberg et al. 1957. F*inal Report on the Possible Effects on the Surrounding Population of an Assumed Release of Fission Products into the Atmosphere from a 300 Megawatt Reactor Located at Lagoona Beach, Michigan*, Project 2506 (Detroit: Atomic Power Development Associates, Inc., May 1957).

Paul Gunter. 1990. “Clamshell Alliance: Thirteen Years of Anti-Nuclear Activism at Seabrook, New Hampshire, U.S.A.,” *Ecologia*, January 1990, no. 3 at http://www.ecologia.org/newsletter/year90/jan90c.html

Joseph Hendrie, 1979. Letter, “NRC Statement on Risk Assessment and the Reactor Safety Study Report (WASH-1400) in Light of the Risk Assessment Review Group Report,” January 18, 1979, to United States Senate.

Richard Hewlett, Francis Duncan, 1974. *Nuclear Navy, 1946-1962* (Chicago: University of Chicago Press, 1974).

Judy Irving et al. 1982. Excerpts from film “Dark Circle” on protest Against Diablo Canyon Nuclear Power Plant, at https://www.youtube.com/watch?v=MPBtwfYcy-M

Journal of Commerce. 1987. “UTILITY-DRAFTED EVACUATION PLAN FOR SEABROOK WINS NRC VOTE,” November 26, 1987, at http://www.joc.com/utility-drafted-evacuation-plan-seabrook-wins-nrc-vote_19871126.html

James Kemmeny, et al. 1979. *The Need for Change: The Legacy of TMI* (Washington: The President's Commission on The Accident at Three Mile Island, October 1979).

Robbie Leppzer. 1978 Film, "Seabrook 1977." https://www.youtube.com/watch?v=N3rS8hzW2pA, uploaded April 10, 2014, as accessed December 24, 2016.

Allison Macfarlane. 2003. "Underlying Yucca Mountain: The Interplay of Geology and Policy in Nuclear Waste Disposal," *Social Studies of Science*, Vol. 33, No. 5, Earth Sciences in the Cold War (Oct., 2003), p. 783-807.

Allison Macfarlane, Rodney Ewing. 2006. *Uncertainty Underground* (Cambridge: MIT Press, 2006).

Scott Malone. 2007. "GE-Hitachi Prep for 'Reemergence' of Nuclear Power," *Reuters*, June 9, 2007, at http://www.reuters.com/article/ge-hitachi-nuclear-idUSN0921484920070709.

George T. Mazuzan. 1982. "Atomic Power Safety: The Case of the Power Reactor Development Company Fast Breeder, 1955-1956," *Technology and Culture*, Vol. 23, No. 3 (Jul., 1982), pp. 341-371.

George T. Mazuzan. 1986. "'Very Risky Business': A Power Reactor for New York City," *Technology and Culture*, XXVII (1986), 262-284.

Richard Meehan. 1984. *The Atom and The Fault* (Cambridge: MIT Press, 1984).

Mooz, William. 1978. *Cost Analysis of Light Water Reactor Power Plants*. R-2304-DOE (Santa Monica: Rand Corporation, June 1978).

Dorothy Nelkin. 1981. "Some Social and Political Dimensions of Nuclear Power: Examples from Three Mile Island," *The American Political Science Review*, Vol. 75, No. 1 (Mar., 1981), pp. 132-142.

New York Times. 1983. "At Indian Pt., A History of Nuclear Power, Problems and Controversy," *NYTimes*, May 6, 1983, at http://www.nytimes.com/1983/05/06/nyregion/at-indian-pt-a-history-of-nuclear-power-problems-and-controversy.html?pagewanted=all

New York Times. 2014. "Nuclear Power's Promise and Peril," Retrospective report on TMI, April 29, 2014, at https://www.youtube.com/watch?v=_0P9S4F4KpQ, as accessed December 29, 2016.

Frank Newport, "Americans Still Favor Nuclear Power a Year After Fukushima," *Gallup*, March 26, 2012, at http://www.gallup.com/poll/153452/americans-favor-nuclear-power-year-fukushima.aspx

Sheldon Novick. 1969. *The Careless Atom* (Boston: Houghton Mifflin, Co., 1969).

Nuclear Energy Institute. 2016. *US Nuclear Operating Plant Basic Information*, May 2016, at http://www.nei.org/Knowledge-Center/Nuclear-Statistics/US-Nuclear-Power-Plants

Office of Technology Assessment (OTA). 1984. *Nuclear Power in an Age of Uncertainty*. (Washington, D. C.: U.S. Congress, Office of Technology Assessment, OTA-E-216, February 1984).

David Pesonen. 1965. “Atomic Insurance: The Ticklish Statistics." *The Nation*, October 18, 1965, pp. 242-244.

David Pesonen. 2013. Interview, “Atomic Park Smackdown,” December 23, 2013, at Forces of Nature, Environmental Elders Speak, at http://theforcesofnature.com/movies/david-pesonen/

Daniel Pope. 1990. “We Can Wait. We Should Wait." Eugene's Nuclear Power Controversy, 1968-1970,” *Pacific Historical Review*, Vol. 59, No. 3 (Aug., 1990), pp. 349-373.

Daniel Pope. 2008. *Nuclear Implosions: The Rise and Fall of the Washington Public Power Supply System* (New York: Oxford University Press, 2008).

Power Reactor Development Corporation (PRDC). 1968. *Report on the fuel melting incident in the Enrico Fermi Atomic Power Plant on October 5, 1966* (Detroit: PRDC, December 15. 1968).

Andrew Pryor. 1977. *Browns Ferry Nuclear Plant Fire*, Society of Fire Protection Engineers, US ERDA Albuquerque, NM SFPE Technology Report 77-2, 1977.

William L. Rankin, Stanley M. Nealey, and Barbara Desow Melber. 1984. “An Overview of National Attitudes Toward Nuclear Energy: A Longitudinal Analysis," in William R. Freudenburg and Eugene A. Rosa, eds., *Public Reaction to Nuclear Power: Are There Critical Masses?* (Boulder, Colo., American Association for the Advancement of Science. Selected Symposium 93, 1984).

Myla Reson, “Davis Besse: Ohio's Costly Nuclear Nightmare,” February 9, 2015, at https://www.youtube.com/watch?v=yefKEDF0uuM as accessed December 25, 2016.

Rebecca Riffkin, “For First Time, Majority in US Oppose Nuclear Energy,” *Gallup*, March 18, 2016, at http://www.gallup.com/poll/190064/first-time-majority-oppose-nuclear-energy.aspx

Michael Rogers. 1981. “Abalone Alliance: Raiders of Diablo Canyon,” *Rolling Stone*, November 12, 1981, at http://www.rollingstone.com/culture/features/raiders-of-diablo-canyon-19811112

“Seabrook Clamshell Alliance.” 1976. *Science for the People*, vol. VIII, no. 6 (November /December 1976), p. 15.

Michael Smith. 1989. “Advertising the Atom,” *Government and Environmental Politics*, ed. Michael Lacey (Washington: Wilson Center Press, 1989), pp. 233-261.

David Sneed. 2014. “Diablo Canyon not as vulnerable to tsunamis as Japan's nuclear plants, PG&E says,” *The Tribune*, March 11, 2014,

http://www.sanluisobispo.com/2011/03/14/1521331/diablo-canyon-nuclear-tsunami.html

Donald Stever, Jr. 1980. *Seabrook and the Nuclear Regulatory Commission: The Licensing of a Nuclear Power Plant* (Hanover, N.H.: University of New England Press, 1980).

James Temples. 1982. “The Nuclear Regulatory Commission and the Politics of Regulatory Reform: Since Three Mile Island,” *Public Administration Review*, Vol. 42, No. 4 (Jul. - Aug., 1982), pp. 355-362.

Sam Thielman. 2016. “Indian Point Nuclear Plant Reeks of Trouble History,” at http://www.theguardian.com/us-news/2016/mar/28/indian-point-nuclear-plant-new-york-troubled-history

Tennessee Valley Authority (?). 1975. Fire at Browns Ferry Nuclear Plant. March 22, 1975 Final Report of preliminary investigating committee. Report to the NRC, May 7, 1975, at https://www.nrc.gov/docs/ML0821/ML082110307.pdf as accessed December 25, 2016.

Three Mile Island Archives. Many years. Dickinson College. At http://archives.dickinson.edu/archives-subject/three-mile-island

Union of Concerned Scientists (UCS). 1970?. “Fermi Unit 1,” http://www.ucsusa.org/sites/default/files/legacy/assets/documents/nuclear_power/fermi-1.pdf accessed December 24, 2016.

Union of Concerned Scientists. 2013. “Seismic Shift: Diablo Canyon Literally and Figuratively on Shaky Ground,” November 2013, Cambridge, MA.

Union of Concerned Scientists (UCS). N.D. “Putting Science to Work,” http://www.ucsusa.org/about/ucs-history-over-40-years.html#.V1KsWHQrLu0 accessed December 24, 2016.

UCS. 2015?. “Indian Point Energy Center,” at http://www.ucsusa.org/nuclear-power/us-nuclear-power-plants-database/indian-point-energy-center#.V1CJEXQrLu1 as accessed June 2, 2016.

US AEC. 1957. WASH-740. *Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants* (Washington: AEC, 1957).

US AEC. 1973. WASH-1250. *The Safety of Nuclear Power Reactors (Light Water-cooled) and Related Facilities* (Washington: AEC ACRS, 1973)

US Department of Energy (DOE). (2000). *America's Nuclear Technology - A Strategic Plan.*

(Germantown: US Department of Energy, Office of Nuclear Energy, Science and Technology, 2000).

US DOE. 2006. Office of Civilian Radioactive Waste Management, *Transportation of Spent Nuclear Fuel and High Level Radioactive Waste to Yucca Mountain. Frequently Asked Questions*, DOE/ONT-0614, Rev. 1 (Washington: DOE, 2006).

US DOE. 2016a. “Office of Nuclear Energy,” at http://www.energy.gov/ne/about-us, as accessed December 24, 2016.

US DOE. 2016b. *Quarterly Nuclear Power Deployment Summary* (Washington: DOE, April 2016).

US GAO (General Accounting Office). 2006a. *Nuclear Regulatory Commission. Oversight of Nuclear Power Plant Safety Has Improved, But Refinements Are Needed*, GAO-06-129 (Washington: GAO, September 2006).

US GAO. 2006b. *Nuclear Power Plants. Efforts Made to Upgrade Security, but the Nuclear Regulatory Commission’s Design Basis Threat Process Should Be Improved*, GAO-06-388 (Washington: US GAO, 2006).

US GAO. 2011. *Commercial Nuclear Waste: Effects of a Termination of the Yucca Mountain Repository Program and Lessons Learned*, GAO-11-229 (Washington: US GAO, April 2011).

US NRC. 2001. "Bulletin : 2001-01: Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles" at http://www.nrc.gov/reading-rm/doc-collections/gen-comm/bulletins/2001/bl01001.html

US NRC. 1975. *Reactor Safety Study*, WASH-1400 (Washington: US NRC, October 1975).

US NRC. 1979. *Draft Environmental Impact Statement Related to Construction of New England Power Units 1 and 2*. (Washington: US NRC, May 1979).

US NRC. 1980. "Nuclear Power Plant Accident Considerations under the National Environmental Protection Act of 1969," *Federal Register*, 45 FR 4010, June 13, 1980.

US NRC. 2001. "Bulletin: 2001-01: Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles" at http://www.nrc.gov/reading-rm/doc-collections/gen-comm/bulletins/2001/bl01001.html

US NRC. 2004?. "Dresden Station Tritium Leak," at http://www.nrc.gov/docs/ML0614/ML061450118.pdf

NRC. 2005. "EA-05-071 - Davis-Besse (FirstEnergy Nuclear Operating Company)," April 21, 2005, at http://www.nrc.gov/reading-rm/doc-collections/enforcement/actions/reactors/ea05071.html

US NRC. 2008. *Davis-Besse Reactor Pressure Vessel Head Degradation*, NUREG/BR-0353, Rev. 1 (Washington: NRC, August 2008).

US NRC. 2013. Office of Nuclear Regulatory Research. *The Browns Ferry Nuclear Plant Fire of 1975 Knowledge Management Digest* NUREG/KM-0002 (Washington: Office of Nuclear Regulatory Research, May 2013).

US NRC. 2014. "Backgrounder on the Three Mile Island Accident," at http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html as accessed December 23, 2016.

US NRC. 2014. "Health Effects," Three Mile Island at http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html#effects, December 12, 2014.

US NRC. 2016a. "About NRC," at http://www.nrc.gov/about-nrc.html, accessed December 19, 2016.

US NRC. 2016b. *Location of Projected New Nuclear Power Reactors*, December 9, 2016, as accessed at http://www.nrc.gov/reactors/new-reactors/col/new-reactor-map.html , December 20, 2016.

US NRC. 2016c. "Special NRC Oversight at Seabrook Nuclear Power Plant: Concrete Degradation,"

http://www.nrc.gov/reactors/operating/ops-experience/concrete-degradation.html June 17, 2016

US SC (Supreme Court). 1961. Power Reactor Development Co. v. Electricians, 367 U.S. 396 (1961),367 U.S. 396 at ttps://supreme.justia.com/cases/federal/us/367/396/case.html.

Matthew Wald. 2011. “Nuclear Industry Thrives in the U. S., But for Export,” *NYTimes*, March 30, 2011, at http://www.nytimes.com/2011/03/31/business/energy-environment/31NUKE.html

Matthew Wald, “Company Struggles to Keep U. S. IN the Uranium Enrichment Game,” *NYTimes*, January 27, 2014, at http://www.nytimes.com/2014/01/28/business/energy-environment/company-struggles-to-keep-us-in-the-uranium-enrichment-game.html?_r=0

J. Samuel Walker. 1990. “Reactor at the Fault: The Bodega Bay Nuclear Plant Controversy, 1958-1964: A Case Study in the Politics of Technology,” *Pacific Historical Review*, Vol. 59, No. 3 (Aug., 1990), pp. 323-348.

Harvey Wasserman. 2015. “Will Ohioans Be Forced to Pay the Bill to Keep the Crumbling Davis-Besse Alive?” *Intrepid Report*, February 17, 2015, at http://www.intrepidreport.com/archives/15266.

Spencer Weart. 1988. *Nuclear Fear* (Cambridge: Harvard University Press, 1988).

Alvin Weinberg. 1979. “Nuclear Energy: Salvaging the Atomic Age,” *The Wilson Quarterly*, Vol. 3, No. 3 (Summer, 1979), pp. 88-112.

Westinghouse. N. d. “Unequaled Safety,” at http://www.westinghousenuclear.com/New-Plants/AP1000-PWR/Safety as accessed December 23, 2016.

John Wills, *Conservation Fallout: Nuclear Protest at Diablo Canyon* (Las Vegas: University of Nevada Press, 2006).

Langdon Winner, *The Whale and the Reactor* (Chicago : University of Chicago Press, 1986).

World Nuclear Association. 2001. “Three Mile Island Accident,” March 2001 (minor update January 2012), at http://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/three-mile-island-accident.aspx.

World Nuclear Association. 2016a. “US Nuclear Policy,” April 2016 at http://www.world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power-policy.aspx

World Nuclear Association. 2016b. “US Nuclear Fuel Cycle” at http://www.world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-fuel-cycle.aspx. Updated November 2016.

6. Appendix 1: Current Status and Plans: Nuclear power in the US

Current Status of the Industry

As of May 2016, 99 nuclear reactors in the US produce electricity, down from a high of 103, 68 of which (69%) are PWRs (pressurized water reactors), and 31 of which (32%) are BWRs (boiling water reactors). (Nuclear Energy Institute, 2016) Fifty-two reactors have net capacity at greater than 1,000 MWe (the largest is Grand Gulf, Mississippi, at 1,400 MW), and 10 of them have net capacity at under 700 MW. They operate largely at 85% to 95% capacity.

There are 61 commercially operating nuclear power plants with 99 nuclear reactors in 30 states in the United States. Thirty-five of these plants have two or more reactors. The Palo Verde power plant in Arizona has three reactors and had the largest combined net summer generating capacity of 3,937 megawatts (MW) in 2014. Fort Calhoun in Nebraska with a single reactor had the smallest net summer capacity at 479 megawatts (MW) in 2014.

In essence, a virtual moratorium on ordering and construction of new reactors was in effect from the mid-1980s because of public concerns about nuclear power connected with the accident at Three Mile Island, Pennsylvania, in 1979, growing costs to design, build and license new reactors, declining demand, low cost for coal and natural gas, and other reasons. The reactors already under construction were completed. According to the US EIA, the last newly built reactor to enter service was Tennessee's Watts Bar 1, a TVA NPP, in 1996, with Watts Bar 2 scheduled to come on line in 2016.

In the meantime, the industry and utilities have determined to pursue extension of operating licenses to terms of operation far longer than the originally forecast lifetimes of nuclear power stations. Some critics worry about whether the margin of safety is sufficient to justify license extensions given the high temperatures, high pressures and radiation regimes under which reactors operate that may subject pumps, piping, pressure vessels, fuel assemblies and other components to great stress, and requiring expensive upgrades.

Eight stations with 12 reactors are currently under review for license renewal, while over fifty stations have completed applications for license renewal and have been approved for extended operation.

In the mid-2000s, as worries about global warming and greenhouse gases associated with fossil fuels grew, representatives of the nuclear industry began to push again to create broad government, utility, and public support for the bringing on line of a new generation of nuclear power stations. As a result, Congress passed the Energy Policy Act of 2005, which is offered extensive subsidies for nuclear power and other alternatives to fossil fuels. It offered billions of dollars in tax credits, loan guarantees for advanced nuclear reactors or other emission-free technologies up to 80% of the project cost, $2 billion in insurance to cover licensing delays to the industry, extension for 20 years of the Price Anderson Act for nuclear liability protection, and support for advanced nuclear technology.

Renewed Interest in Nuclear Power in the 2010s?

In mid-2008, the Department of Energy (DOE) invited applications for loan guarantees to support the construction of advanced nuclear power plants (up to $18.5 billion total) and uranium enrichment plants (up to $2 billion initially, but then $4 billion). A further $78.5 billion was offered for renewable energy projects, and $8 billion for “clean coal.” According to the NRC, as of April 2016, utilities have begun planning to bring 28 new PWRs reactors (at 1,000 MW or greater capacity) on line in the coming years, with applications for 15 of these NPPs received by the NRC. Most are located in southern states and Texas. (US NRC, 2016b) These include 8 Westinghouse AP-1000. Westinghouse calls its new reactor “the most advanced commercially available nuclear power plant,” and touts its advanced passive safety systems for “defense in depth,” using gravity rather than operator invention to ensure safety. In the event of a design-basis accident, such as a main coolant-pipe break, the plant is designed to achieve and maintain safe shutdown condition without operator action, and without the need for ac power or pumps. Rather than relying on active components, such as diesel generators and pumps, the AP1000 plant relies on natural forces - gravity, natural circulation and compressed gases - to keep the core and the containment from overheating. (Westinghouse, n. d.)

Fukushima

The nuclear disaster at Fukushima in March 2011 may have dampened hopes for new reactor permits and construction starts, even with these multi-billion dollar subsidies, and has certainly provoked response among a broad sector of the public about the risks of a catastrophic nuclear accident. The public favored nuclear solution to future energy needs after Fukushima, but in 2016 a majority seem to be against nuclear futures. (Newport, 2012; Riffkin, 2016)

Nuclear Futures in the US

The US Energy Policy Act of 2005 offered significant subsidies for nuclear power and other alternatives to fossil fuels, demonstrating that Congress tends to ignore its stated mantra that market mechanisms are preferable to government funding of expensive technologies through billions of dollars in tax credits, loan guarantees, and insurance to cover licensing delays. In response to the Act, a number of large utilities and manufacturers turned from build coal-fired boilers to reactors. The nuclear industry touted the climate-friendliness of NPPs. CEO Jeff Immelt of GE said in 2007, “It's hard to believe simultaneously in energy security and reduction of greenhouse gas emissions without believing in nuclear power. It’s just intellectually dishonest.” Immelt saw as many as five reactors being built annually throughout the world in a matter of years. (Malone, 2007)

The Energy Policy Act included the following incentives for the domestic nuclear power industry:

- Production tax credit of 1.8 or 2.1 ¢/kWh from the first 6,000 MWe of new nuclear capacity in their first eight years of operation (the same rate as available to wind power on an unlimited basis).
- Federal risk insurance of $2 billion to cover regulatory delays in full-power operation of the first six advanced new plants.
- Rationalized tax on decommissioning funds (some reduced).
- Federal loan guarantees for advanced nuclear reactors or other emission-free technologies up to 80% of the project cost.
- Extension for 20 years of the Price Anderson Act for nuclear liability protection.
- Support for advanced nuclear technology.

Also $1.25 billion was authorized for an advanced high-temperature reactor (Next Generation Nuclear Plant) to be built at INL capable of cogenerating hydrogen. In 2006, it was spelled out that the 6000 MWe eligible for production tax credits would be divided pro-rata among those applicants which filed combined construction and operating license (COL) applications by the end of 2008, which commence construction of advanced plants by 2014, and which enter service by 2021.

In October 2007, DOE announced that it would guarantee the full amount of loans covering up to 80% of the cost of new clean energy projects including advanced nuclear power plants under the 2005 Energy Policy Act. The first round of loan guarantees went to renewable energy and advanced gas (*e.g.* integrated gasification combined cycle) projects, while those for nuclear had to be authorized by Congress. In mid-2008, DOE invited applications for loan guarantees to support the construction of advanced nuclear power plants (up to $18.5 billion total) and uranium enrichment plants (up to $2 billion initially, but then $4 billion). A further $78.5 billion was offered for renewable energy projects, and $8 billion for “clean coal.” Loan guarantees are to encourage the commercial use of new or significantly improved energy technologies and “will enable project developers to bridge the financing gap between pilot and demonstration projects to full commercially viable projects that employ new or significantly improved energy technologies.” They are a form of support that allows companies to finance debt at reduced rates.

Yet even in France, the most active nuclear power in the 2010s, and even with Russian Rosatom’s self-proclaimed “nuclear renaissance,” it seems unlikely Immelt’s prediction can be met. To be sure, no new reactor has come on line yet in the US, and the earliest date may be 2020. Beyond costs and delays, many people oppose nuclear technology, not only because of the Fukushima disaster in March 2011, but because of fear of terrorism, on top of which gas and oil processes have dropped precipitously. Perhaps the major argument for nuclear power in 2016, then, is the argument that nuclear power does not produce greenhouse gases.

NRC Ongoing Reviews of Licenses for NPPs in the 2010s

In the US, in 2013, the Nuclear Regulatory Commission (NRC) was reviewing nine applications for combined construction and operating licenses (COLs) to build 14 new nuclear reactors, as well as three design certification applications for new reactor types (EPR, ESBWR & APWR) and two design certification renewals (both ABWR). Just three years later 18 COL applications had been docketed; four received COLs; five (totaling 8 nuclear reactors) remained under active of the NRC, and 9 were suspended due to utility economic or other considerations. A Reference COL (R-COL) application has been submitted for five reactor designs; subsequent COLs (S-COLs) will incorporate the corresponding R-COL application by reference, noting any site-specific departures. Southern Nuclear's Vogtle units 3 and 4, SCE&G's V.C. Summer units 2 and 3, DTE Energy's Fermi unit 3, and have received COLs.(DOE, 2016b: 1)

TVA expects Watts Bar 2 to enter commercial operation by mid-2016. Southern Nuclear's Vogtle units 3 and 4 are expected to come online in mid-2019 and 2020, respectively. And SCE&G's V.C. Summer units 2 and 3 are expected to come online in mid-2019 and 2020, respectively. (DOE, 2016b: 3)

To quote the World Nuclear Association at length, in 2008, with a fee of $200,000 for the first part and $600,000 for the second part, the government

> received 19 initial applications from 17 utilities to support the construction of 14 nuclear power plants involving 21 new reactors of five different designs. The total capacity involved was 28,800 MWe. The total requested came to $122 billion, significantly more than the $18.5 billion offered. The aggregate estimated construction cost involved the 14 projects was $188 billion. The DOE also received two applications for enrichment plants, total $4 billion, against $2 billion initially on offer. (World Nuclear Association, 2016b)
>
> In the light of the interest shown and the fact that the scheme is borrower-funded, the industry called for the amount available for power plants to be increased to $100 billion. In February 2010, the Administration added $36 billion to its FY2011 budget proposal to expand the reactor part of the scheme to $54.5 billion, covering 6 to 8 projects involving up to 13 reactors of several different designs, but this was not approved by Congress. In February 2011 the request was repeated for FY 2012 but was again refused. The FY 2013 budget proposal contained no such request. In the meantime, DOE conditionally granted the applications for one project (Vogtle) and sought to increase the $8.3 billion sum available before October 2010 by $9 billion through other legislation, so that it could approve the other three short-listed power plant applications involving five reactors. (Ibid.)

7. Appendix 2: List of Anti-nuclear Groups in the US (from wiki)

Groups include:

- Abalone Alliance
- Alliance for Nuclear Accountability
- Alliance for Nuclear Responsibility
- Arms Control Association
- Beyond Nuclear
- Citizens Energy Council
- Cactus Alliance (in Utah)
- Catfish Alliance (in Alabama)
- Nuclear Energy Information Service of Chicago (NEIS)
- Citizen's Committee for Protection of the Environment
- Clamshell Alliance
- Coalition for Nuclear Power Postponement
- Committee for a Nuclear Free Island
- Committee for a Nuclear Overkill Moratorium
- Committee for Nuclear Responsibility
- Concerned Citizens Against the Bailly Nuclear Site
- Corporate Accountability International
- Council for a Livable World
- Crabshell Alliance (in Seattle)
- Critical Mass
- Musicians United for Safe Energy
- North Anna Environmental Coalition
- Nevada Desert Experience
- New England Coalition
- Nuclear Age Peace Foundation
- Nuclear Control Institute
- Nuclear Disarmament Partnership
- Nuclear Information and Resource Service
- Nuclear Policy Research Institute
- Nuclear Threat Initiative
- Nuclear Watch of New Mexico
- Nuclear Watch South
- Oystershell Alliance (in New Orleans)
- Palmetto Alliance (in South Carolina)
- Peace Action
- People's Alliance for Clean Energy
- Physicians for Social Responsibility
- Pilgrim Watch
- Plowshares Movement
- Public Citizen
- Red Clover Alliance (in Vermont)

- Don't Make a Wave Committee
- Economists for Peace and Security
- Environmental Coalition on Nuclear Power
- Federation of American Scientists
- Friends of the Earth
- Heart of America Northwest
- Greenpeace
- Institute for Energy and Environmental Research
- Lawyers' Committee on Nuclear Policy
- Maryland Public Interest Research Group
- Mothers for Peace
- Rocky Flats Truth Force
- Riverkeeper
- Shad Alliance
- Shundahai Network
- Sierra Club
- Southern Alliance for Clean Energy
- Seneca Women's Encampment for a Future of Peace and Justice
- Two Futures Project
- Tri-Valley CARE
- White House Peace Vigil
- Wisconsin Project on Nuclear Arms Control
- Women Strike for Peace

Source: http://en.wikipedia.org/wiki/Anti-nuclear_groups_in_the_United_States

8. Appendix 3: Reactor Safety Studies

In the effort to encourage rapid commercialization of nuclear power, the AEC encountered the challenge of balancing public safety with promotion of nuclear power at a stage when the technology of commercial reactors was at an early stage of development. The problem of estimating risk of a catastrophic accident persisted as reactors grew manyfold in size. As they grew in size, so too determining how far to site from population centers became more difficult. AEC commissioners and staff considered siting, emergency reactor core cooling, seismic safety and a series of other issues, in the process often determining that the utilities and reactor manufacturers managers would do the right thing (in terms of safety) even in the absence of complete information. AEC procedures were necessarily ad hoc since these decisions occurred in often uncharted territory. As a result, the AEC too often assumed a promotional, not sufficiently regulatory role.

Brookhaven National Laboratory (March 1957)

WASH-740 scientists concluded that “if the assumed accident happened under what is known as a common nocturnal inversion condition, the lethal cloud of radioactive gases and particles would kill an estimated 3,400 people within 15 miles of the plant. Severe radiation sickness would fell another 43,000 people up to 44 miles away from the accident. Another 182,000 people up to 200 miles away from the source would be exposed to a dose that would double the chances of cancer. Property damage alone would amount to $7 billion about 10 percent of the government receipts at the time in 1957.” WASH-740 also concluded that if containment worked, there would be no danger to the surrounding population. (AEC, 1957)

Gomberg at al. on the “Enrico Fermi” LMFBR (1957)

Gomberg et al. warned in 1957 on the potential for massive and fatal exposures over a large region with millions of residents – depending on wind speed and direction and weather – in the face of the effort quickly to license and build an untried, new technology (a commercial liquid metal fast breeder reactor) near Detroit. (Gomberg, 1957)

ORNL and INL (Idaho National Laboratory, from 1949 the National Reactor Testing Station) (1960s)

A series of experiments in 1960s at ORNL and INL revealed that a LOCA would have a devastating impact and that it would be challenging to get an ECCS to operate in time within parameters.

WASH-1250 (1973)

WASH-1250 was published on a very limited basis as a final draft in July 1973 contains a brief discussion about the development of public sentiment toward nuclear energy in the United States from inception up to the time of publication of this final draft in 1973. (AEC, 1973)

WASH 1400 “Rassmussen” (1975)

WASH-1400, conducted under chairmanship of MIT Professor Norman Rasmussen, considered the course of events that might arise during a serious accident at a large PWR or BWR. It estimated the radiological consequences of these events, and the probability of their occurrence, using a fault tree/event tree approach based on Probabilistic Risk Assessment. The report concluded that the risks to the individual posed by nuclear power stations were acceptably small, compared with other tolerable risks. The report concluded the probability of a complete core meltdown is about 1 in 20,000 per reactor per year. “Contrary to commonly held belief,” the researchers observed, the probability is high “that the consequences” of a core melt accident would be modest to other types of risks. “The likelihood of relatively severe consequences is quite low.” On top of these “the consequences of reactor accidents are often smaller than many people have believed.” Previous studies were based on “unrealistic assumptions” that predicted “relatively large consequences” for reactors that were much smaller than current reactors.” Finally, the likelihood of reactor accidents was smaller than that of many other accidents having similar consequences.” The authors noted that we do not live in a risk free society and never will. But “what level of risk from nuclear accidents should be accepted by society has not been addressed in this study.” (US NRC, 1975)

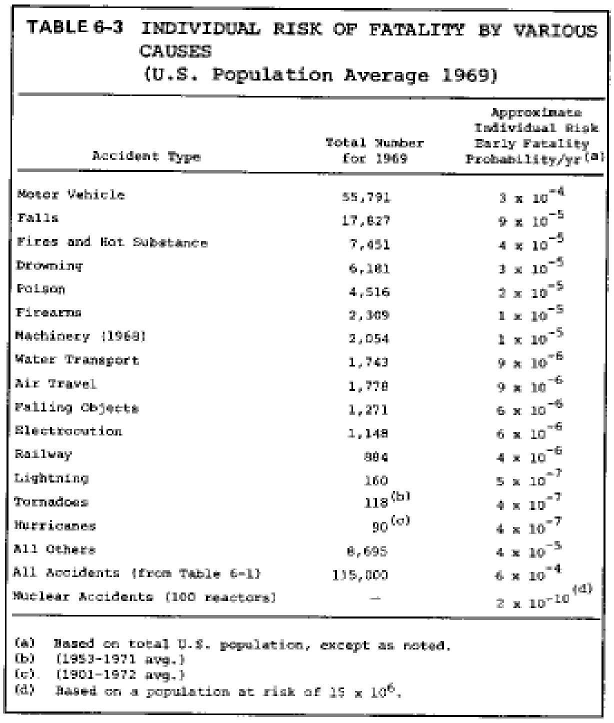


TABLE 6-3 INDIVIDUAL RISK OF FATALITY BY VARIOUS CAUSES
(U.S. Population Average 1969)

Accident Type	Total Number for 1969	Approximate Individual Risk Early Fatality Probability/yr (a)
Motor Vehicle	55,791	3×10^{-4}
Falls	17,827	9×10^{-5}
Fires and Hot Substance	7,451	4×10^{-5}
Drowning	6,181	3×10^{-5}
Poison	4,516	2×10^{-5}
Firearms	2,309	1×10^{-5}
Machinery (1968)	2,054	1×10^{-5}
Water Transport	1,743	9×10^{-6}
Air Travel	1,778	9×10^{-6}
Falling Objects	1,271	6×10^{-6}
Electrocution	1,148	6×10^{-6}
Railway	884	4×10^{-6}
Lightning	160	5×10^{-7}
Tornadoes	118 (b)	4×10^{-7}
Hurricanes	90 (c)	4×10^{-7}
All Others	8,695	4×10^{-5}
All Accidents (from Table 6-1)	115,000	6×10^{-4}
Nuclear Accidents (100 reactors)	–	2×10^{-10} (d)

(a) Based on total U.S. population, except as noted.
(b) (1953-1971 avg.)
(c) (1901-1972 avg.)
(d) Based on a population at risk of 15×10^6.

US NRC, *Reactor Safety Study*, WASH-1400 (Washington: US NRC, October 1975), p. 112.

WASH-1400 provoked extensive commentary and criticism. According to Wiki, for instance, a panel of American Physical Society (APS) criticized WASH-1400 for making fatality estimates only deaths during the first 24 hours after an accident and ignoring other pathways of exposure, let alone the long period before many cancers might arise. Several studies found estimates of probabilities to be too low, others too high. The Union of Concerned Scientists published a highly critical report of WASH-1400 in 1977 for “seriously” underestimating the hazards of nuclear reactor accidents. They argued that the risk of a reactor accident in the early 1980s “is over 400 times greater than that predicted by the reactor safety study” – largely because of the methodology used. In June 1976, the House Subcommittee on Energy and Environment held hearings on WASH-1400, leading the NRC to convene a study group to examine the validity of the report's conclusions under Harold Lewis of the University of California that concluded that "the uncertainties in WASH-1400's estimates of the probabilities of severe accidents were in general, greatly understated.” In 1979 the NRC accepted the criticisms and withdrew its endorsement of the executive summary. (US NRC, 1980; Hendrie, 1979)

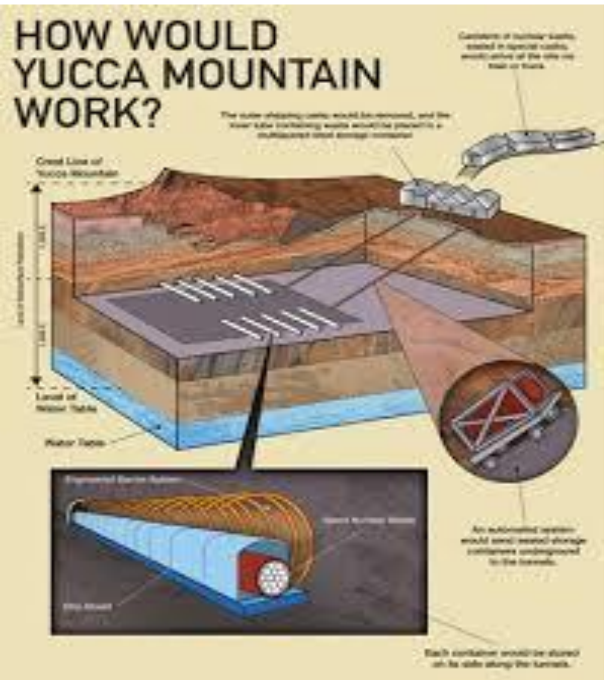
By the 1970s already fifty reactors had come on line, and few of them had ECCS.

9. Appendix 4: Radioactive Waste and Spent Nuclear Fuel

To date, no comprehensive action has been taken to solve the problem of the accumulation of radioactive waste and spent fuel at power stations around the country, the latter amount which has reach 70,000 tons stored in basins or in dry cask storage at the power stations themselves and may be at risk, according to the US Academy of Sciences, from terrorist attack.

Long-term Disposal and Yucca Mountain

Shepherded through a long political process that was intended to select a geographically and scientifically sound place for disposal of radioactive waste, including the 70,000 tons of spent fuel from the operation of 104 commercial reactors, the US DOE selected Yucca Mountain as a site for deep burial. The Nuclear Waste Policy Act of 1987 specified a deep geological repository. Long term, costly, scientific and cultural disputes led to the abandonment of Yucca Mountain even after a number of preliminary tunnels and storage areas had been drilled. But after being initially approved by the Bush administration in 2002, the Obama administration abandoned the site.


HOW WOULD YUCCA MOUNTAIN WORK?
Crest Line of Yucca Mountain
Level of Water Table
Water Table
An automated system would send sealed storage containers underground to the tunnels.
Each container would be stored on its side along the tunnels.

The Secretary of Energy asserted to President George W. Bush in 2002 that “sound science” supported the decision to move ahead with Yucca Mountain Repository. But as Rodney Ewing and Allison Macfarlane argued, a number of government agencies that reviewed the suitability of the site determined among other things that “relies on modeling assumptions that mask a realistic assessment of risk” and that “computations and analyses are assumption-based, not evidence-supported.” The GAO concluded that, “DOE will not be able to submit an acceptable application to NRC within the express statutory time frames for several years because it will take that long to resolve many technical issues.” Ewing and Macfarlane write that “The necessary science to support this decision requires an analysis that couples atomic-scale processes, such as spent fuel and waste package corrosion, to crustal-scale processes, such as volcanic activity and climate change, that extend over temporal scales of thousands, if not tens of thousands, of years.” They concluded “At Yucca Mountain, the passive properties of the repository site do not provide a long-term barrier to radionuclide release. The concept of placing spent nuclear fuel in the unsaturated zone where it will experience oxidizing conditions is simply a poor strategy.” Other uncertainties include the frequency and impact of volcanic activity, the role of sorption in the unsaturated zone in reducing radionuclide mobility, and the role of colloids in enhancing transport. They called for further study to ensure that Yucca Mountain “may be judged to be an adequate site for the disposal of nuclear waste, but a project of this importance, which has gone on for 20 years, should not go forward until the relevant scientific issues have been thoughtfully addressed.” (Ewing and Macfarlane, 2002: 659-670; Macfarlane, 2003)

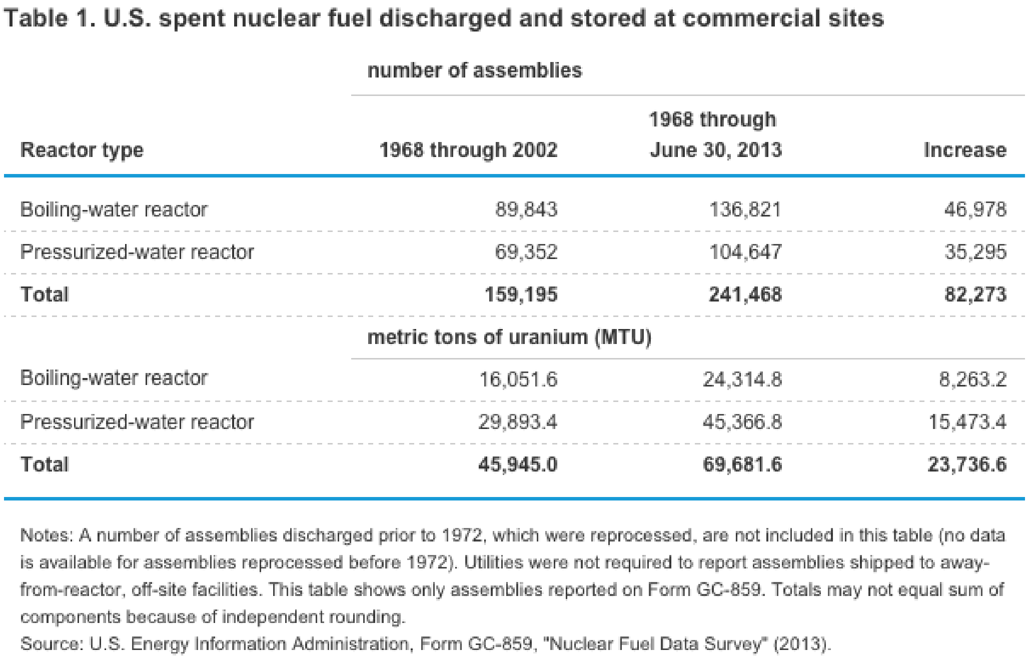


Table 1. U.S. spent nuclear fuel discharged and stored at commercial sites

Reactor type	1968 through 2002	1968 through June 30, 2013	Increase
	number of assemblies		
Boiling-water reactor	89,843	136,821	46,978
Pressurized-water reactor	69,352	104,647	35,295
Total	**159,195**	**241,468**	**82,273**
	metric tons of uranium (MTU)		
Boiling-water reactor	16,051.6	24,314.8	8,263.2
Pressurized-water reactor	29,893.4	45,366.8	15,473.4
Total	**45,945.0**	**69,681.6**	**23,736.6**

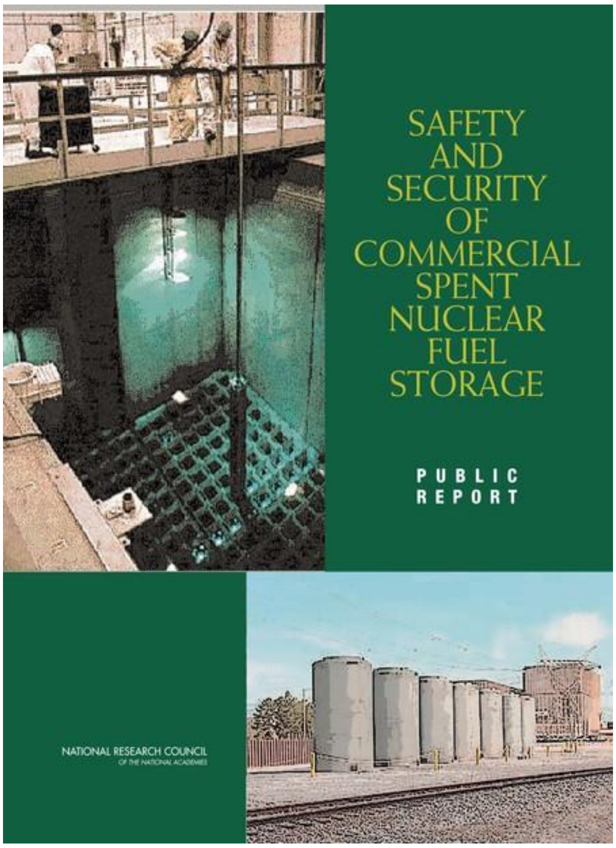
Notes: A number of assemblies discharged prior to 1972, which were reprocessed, are not included in this table (no data is available for assemblies reprocessed before 1972). Utilities were not required to report assemblies shipped to away-from-reactor, off-site facilities. This table shows only assemblies reported on Form GC-859. Totals may not equal sum of components because of independent rounding.
Source: U.S. Energy Information Administration, Form GC-859, "Nuclear Fuel Data Survey" (2013).

The administration of President Obama abandoned the site after 20 years of effort in 2008, and after several billion dollars of effort. The GAO criticized the decision as political, not scientific, (GAO, 2011) and pointed to the liability of the government for up to $15.4 billion because of industry lawsuits. There is a great deal of scientific uncertainty about the seismic and other characteristics of the site. Also the Shoshone people rejected Yucca Mountain as their land, a violation of a treaty with them, and they want their land inviolable to any more nuclear incursions. Ultimately, the absence of a facility indicates yet one more obstacle standing in the way of rejuvenated nuclear in the US.

The repository would have accepted about 175 shipments by train and truck every other day for 24 years in “robust” transportation containers or casks designed to protect them again puncture, immersion, thermal risk or a highspeed crash. (US DOE, 2006)

Terror and SNF

According to the National Academy of Sciences, spent nuclear fuel stored in pools at some of the nation’s commercial nuclear reactors may be at risk from terrorist attacks. The Board on Radioactive Waste Management issued a report that calls on the NRC to conduct additional analyses to obtain a better understanding of potential risks and to ensure that power-plant operators take prompt and effective measures to reduce the possible consequences of such attacks. Because potential threats may differ according to a specific plant's design, the committee recommended that plant-by-plant vulnerability analyses be performed. The Bush administration attempted to classify and prevent publication of parts of this report.


SAFETY
AND
SECURITY
OF
COMMERCIAL
SPENT
NUCLEAR
FUEL
STORAGE

PUBLIC
REPORT

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

The GAO pointed to some improvements made on physical security but noted that others in the design basis to threats must be improved. (US GAO, 2006)

Nuclear Fuel

The United States has an extensive nuclear fuel industry whose roots are with the Manhattan Project (the atomic bomb project) and the construction of the Oak Ridge (later ORNL) gaseous diffusion facility for the separation of U^{235} from non-fissile U^{238}, and the Hanford, Washington, site for plutonium production. Later other facilities were added to produce enriched uranium at Paducah, Kentucky, and Piketon, Ohio (closed in 2001). Centrifuge production of enriched uranium has occurred in Eunice, NM, Bonneville County, ID. The only US facility that enriches uranium in 2016, USEC, in Eunice, NM, has struggled with bankruptcy pressures, so that uranium enrichment, pioneered in the US, “may become primarily a European and Russian technology.”(Wald, 2014) Currently, almost all the uranium used in US commercial reactors is imported. After reaching a peak in 1980, domestic mining now accounts for only 10% of the fuel used in US reactors. Between 1977 and 2005, government policy did not allow reprocessing of used fuel for commercial reactors.

Fuel Actors in 2010s (World Nuclear Association, 2016b)

Thus the US currently has one operating enrichment plant owned by Urenco (formerly National Enrichment Facility), and USEC's Paducah, Kentucky facility built by the government in the early 1950s to provide fuel for military reactors. Two proposed enrichment plants could begin operation around 2020. In addition, USEC had started building its own enrichment plant, the American Centrifuge Plant in Piketon, Ohio, which had been due to begin operation in 2010, but the project was put on hold in July 2009. In 2014 USEC became Centrus Energy Corp as it emerged from bankruptcy.

Urenco USA (formerly National Enrichment Facility) has a major centrifuge enrichment plant at Eunice, New Mexico. It uses 6th generation Urenco technology from Europe and was planned by the Louisiana Energy Services (LES) partnership – comprising Urenco, Exelon, Duke Power, Entergy, and Westinghouse. Construction of the $1.5 billion plant was licensed by the Nuclear Regulatory Commission (NRC) in mid-2006 when as agreed the three utilities then passed their share to Urenco, and the company is now a subsidiary of Urenco USA. Utility support for the venture – initially amounting to $3.15 billion in orders – was crucial in persuading the NRC that further US enrichment capacity was required beyond that provided and envisaged by USEC.

The USEC and Paducah old plant was the last gaseous diffusion plant still operating in the world, having been commissioned in 1952 for military use. It began providing enriched uranium for civilian reactors in the 1960s. Originally government-owned, USEC became a private sector corporation in 1998, and leased its two large enrichment plants from the DOE. In 2001, it consolidated its enrichment operations at the Paducah site after closing the older Portsmouth facility at Piketon, Ohio[b]. Both plants were very energy-intensive and costly to run.

In November 2013 the DOE announced that it had selected a proposal from **Global Laser Enrichment** (GLE) to build a plant to enrich uranium. In the same announcement, the DoE said it would enter negotiations with Areva to process off-specification uranium hexafluoride as blend stock for domestic nuclear fuel. This would be carried out using Areva's existing nuclear fuel fabrication facility in Richland, Washington. DOE said that the GLE and Areva projects represented "an important next step" in planning for potential future uses and clean-up efforts at Paducah as well as reducing the costs to the taxpayer of the clean-up operation. Fluor has a three-year $420 million DOE contract to clean up the Paducah site from 2014.

The United States Enrichment Corporation (Centrus)[1]

"In the 1960s, it began providing commercial sales of enriched uranium to the commercial nuclear power industry worldwide. Over the next twenty years, the U.S. government's uranium enrichment complex became the primary supplier of low-enriched uranium to reactor operators around the world, helping to promote the peaceful use of nuclear power and advance the nation's nonproliferation agenda. In the 1970s, the Nixon administration first proposed the privatization of the government's enrichment business. Two decades later, the Energy Policy Act of 1992 created the United States Enrichment Corporation, a government corporation, out of the U.S. Department of Energy's Uranium Enrichment Enterprise, with plans to eventually fully privatize the government's uranium enrichment organization. The new government corporation began operations in July 1993.

'The U.S. government sold the company in an initial public offering in 1998, and USEC Inc., a private, investor-owned company, began trading on the New York Stock Exchange. Proceeds from the sale provided more than $3 billion to the U.S. Treasury. The company continued to operate the country's Cold War era enrichment plants safely and efficiently until the last one was shut down for economic reasons in 2013.

"In the early 1990s, the United States and Russia reached a landmark agreement that would turn former Soviet nuclear weapons material into fuel to power America's civilian nuclear reactors. The company played a key role in implementing the deal, marketing the downblended material to U.S. utilities and arranging for deliveries. From 1993 to 2013, the "Megatons to Megawatts" partnership provided enough fuel to generate 10% of America's electricity needs. It was the most successful non-proliferation effort in history – eliminating more than 20,000 warheads worth of weapons-grade material. That corresponds to the elimination of three bomb equivalents per day for twenty years.

“After a financial restructuring in 2014, the company re-emerged as Centrus Energy Corp., with a stronger balance sheet and a new board of directors. In 2015, the Board selected a new leadership team, which is focused on expanding and diversifying its business. Today, the company has a multibillion-dollar long-term order book with customers around the world, a diverse base of nuclear fuel supply contracts stretching to 2026 and beyond, world-class technical capabilities, and a strong market opportunity as the global nuclear industry continues to grow.”